JOURNAL OF AGRICULTURAL RESEARCH
DEPARTMENT OF AGRICULTURE

VOL. V WASHINGTON, D. C., MARCH 20, 1916 NO. 25

INHERITANCE OF FERTILITY IN SWINE[1]

[PRELIMINARY PAPER]

By EDWARD N. WENTWORTH, *Professor of Animal Breeding*, and C. E. AUBEL, *Fellow in Animal Breeding, Kansas Agricultural Experiment Station*

INTRODUCTION

Mendelian inheritance applies almost without exception to the transmission of qualitative characters. Quantitative traits, on the other hand, are susceptible only to a generalized treatment from this viewpoint, and few investigators have attacked the problem. Size inheritance in animals has been dealt with by Castle and Phillips (2)[2], Goldschmidt (7), MacDowell (10), Phillips (19, 20), and Punnett and Bailey (21), while Detlefsen (3) has treated the inheritance of certain skeletal characters. Pearl, (15) discovered an arbitrary division point of 30 eggs in the winter laying period of hens, for which inheritance apparently depends on two factors, one of which follows an ordinary Mendelian, and the other a sex-linked scheme. These determiners provide the nearest to units of inheritance that have yet been isolated in quantitative studies.

Because of the fact that fecundity deviates only by discrete units, the litter size in swine provides peculiarly favorable material for studying quantitative inheritance. An analysis of this material has already been attempted from the biometric viewpoint. Rommel and Phillips (24) correlated the size of litters in which dams and daughters were farrowed and found a correlation coefficient of 0.0601 ± 0.0086. They conclude from this result that there is an actual positive correlation between the size of litters of two successive generations, believing that size of litter is a character transmitted from mother to daughter. They recognize the smallness of the coefficient, but believe the indications of inheritance are large enough to provide a basis for selection. In studying fertility inheritance Pearson and Lee (18) obtained practically similar coefficients with the human race and the thoroughbred horse. The range of correlation was 0.0418 to 0.213; hence, they conclude that fertility is certainly and markedly inherited.

[1] Paper No. 1 from the Laboratory of Animal Technology, Kansas Experiment Station.
[2] Reference is made by number to "Literature cited," p. 1159-1160.

Rommel and Phillips (24) studied the inheritance only through the female line, taking no account of a possible influence of the male. George (6) correlated the size of litter with that of the paternal and maternal grandams, respectively. Only 296 litters were involved in his populations; hence, his probable errors were large. But in the dam and daughter comparisons he approximated very closely the result obtained by Rommel and Phillips. His four coefficients follow:

Daughter and dam	0.0615±0.0390
Dam and grandam	.1147± .0343
Daughter and maternal grandam	.0025± .0392
Daughter and paternal grandam	.0508± .0392

None of these correlations are three times as large as their probable error; hence, none are really significant.

Simpson (25) approached the problem from a Mendelian standpoint by crossing a wild German Schwarzwald boar to a young Tamworth sow. The Schwarzwald normally averages 4 pigs to the litter, the Tamworth about 11. The particular sow used was farrowed in a litter of 12 pigs, and to the stint of the wild boar farrowed 9 pigs. In the F_1 generation three females were bred, one to a litter mate and the other two to sires unnamed. The first sow produced 4 pigs, the others 4 and 6, respectively, all in their first litters. The sow producing the 6-pig brood was later served by a pure Schwarzwald boar and farrowed 7 pigs, being apparently constant for that degree of fertility. One of the sows from the brood of 6 gave birth to 12 pigs when mated to a pure Tamworth male. The evidence for a segregation of fecundity factors seems fairly clear, although the numbers are small.

NONGENETIC FACTORS AFFECTING FERTILITY

External factors play a great part in the realization of the inborn hereditary capacity for reproduction. Marshall (12, 13) discusses at length the relation between season and productivity, while the sterility of wild animals in captivity or of domestic animals transferred to vastly different altitudes is proverbial. Marshall and Evvard (4, 5) have both studied the effect of "flushing" in sheep, and Evvard has conducted some very exhaustive investigations into the relation of the various compounds of nutrition to litter size in swine. Using the rate of gain at breeding time in gilts [1] as an indication of the state of nutrition, Evvard has found as much as an average difference of two pigs per litter in favor of the best gainers in each experimental lot, when compared with the poorest gainers. Protein added to a nitrogen-deficient ration (corn alone) produced a marked rise in the fertility of gilts and a medium rise in the fertility of older sows.

Many stockmen believe that overfatness diminishes fecundity. There may be both a physical obstruction of the reproductive organs due to

[1] A gilt is a young sow intended for breeding purposes. The term is usually applied only until the first litter is produced, although it is sometimes extended throughout the suckling period.

fat and an adipose degeneration of the sex glands. Whether these are really causes of decreased fertility is doubtful, since the best evidence shows them to be symptoms of reproductive derangement.

Overfatness occurs frequently as a result of disturbances in the metabolism, due to loss of secretion from several of the ductless glands, the sex gland being here included. Castrating or spaying are known to promote obesity; hence, it is quite reasonable to assume that if testicular or ovarian derangement first occurs, then fat deposition will follow. Overfatness would thus merely indicate and not initiate reduced fecundity.

Market hog raisers usually believe that pure-bred hogs are deteriorating in prolificacy, in line with the common idea that inbreeding ultimately results in barrenness. Bitting, in 1898 (1), investigated the average size of the first 200 litters and the last 200 litters recorded at that time in the herdbooks of the Berkshire, Ohio Poland-China, Standard Poland-China, and Improved Chester White registry associations and found that during the period in which registration had taken place the Berkshires had decreased 0.19 pig per litter, the Poland-China had increased 0.225 pig, and the Chester White had increased 0.1 pig. Rommel (22) investigated the same point for a period of 20 years in books of the American and Ohio Poland-China associations, comparing the average size of litter for the first 5 years with the average for the last 5. The increase was 0.62 pig per litter among the American Poland-Chinas and 0.43 pig per litter in the Ohio strain. A similar study by Rommel (22) on the Duroc-Jersey covering over 15 years showed an increase of 0.57 pig. The changes which have occurred here are manifestly opposed to the idea that purity of blood lines diminishes fertility. On the other hand, the purity of blood can not be credited with the increase, since a constant selection for large litters has taken place, although an increased homozygosis for prolificacy might come about gradually with years of such mass selection as ordinary stock breeding involves.

Hammond (8) has shown that ova may be lost either before or after fertilization; and, still more important, he has discovered that a relatively high percentage may atrophy during the earlier stages of embryonic growth. Lewis (9) indicated that there may be morphological interferences with reproduction, so that fertility may be decreased. He found that the sperm cells of the boar are practically all dead after being in the uterus for 48 hours, which would, of course, result in a reduced fertility. Lewis's results on the viability of sperm differ from those of Dührssen (11), who observed living sperms in the Fallopian tubes of a woman patient three weeks after copulation had taken place. The importance of this question is probably confined to individual cases.

Certain relatively extraneous characters are popularly supposed to be correlated with high fertility. Many farmers believe that "big type" or "cold blooded" hogs farrow larger litters than "hot blooded," or

that "Spotted Poland-Chinas" are far more fecund than ordinary strains. Swine judges commonly consider long-bodied sows more prolific than their chubbier mates. A comparison of 1,000 litters of "large type" Poland-Chinas with 1,100 litters of "small type" showed no significant difference in fertility. The mean for the "large type" was 7.854 ± 0.0456, and for the "small type" was 7.896 ± 0.0436. Furthermore, the standard deviation of the two groups was almost exactly the same, being 2.142 ± 0.0323 for the former and 2.146 ± 0.0309 for the latter. The writers have never seen more than isolated instances brought forward to confirm the popular ideas on this subject and feel that the bulk of such beliefs have resulted from mere advertising schemes.

Breed certainly has its influence. Bitting (1) has averaged the litter sizes for 400 Berkshires, 1,086 Poland-Chinas, and 600 Chester Whites, with the following results:

Berkshire	8.22 pigs per litter.
Poland-China	7.45 pigs per litter.
Chester White	8.96 pigs per litter.

Surface (26) computed the means and standard deviations in the 54,515 litters of Poland-Chinas and the 21,652 litters of Duroc-Jerseys studied by Rommel (22). His constants follow:

	Mean.	Standard deviation.
Poland-China	7.435 ± 0.01	2.038 ± 0.013
Duroc-Jersey	$9.337 \pm .021$	$2.427 \pm .016$

The large numbers here involved undoubtedly prove that real breed differences in fertility exist.

Pearl (15, 16) found the number of mammæ to be correlated positively with the number at a birth when different species are compared, but the coefficient is very low within the species. Parker and Bullard (14) correlated the same characters in 1,000 litters of swine and obtained a coefficient of 0.0035 ± 0.0124. The senior author[1] treated the same point in 170 litters of which he had made genetic studies and obtained a coefficient of -0.0059 ± 0.0517.

These figures certainly demonstrate that the number of mammæ in swine is not related to fertility; in fact, nothing so far discussed presents reliable external characters on which fertility selections can be made. Apparently fecundity has as profound a genetic as physiologic basis.

VALUE OF HERDBOOK DATA

There is now on record an immense mass of data relating to fertility inheritance in swine, in the volumes of the different breed registry associations. In addition to the name and number of the animal, its parents, breeder, etc., the size of litter in which it was farrowed is usually stated.

[1] Unpublished data.

This furnishes opportunity to link together any desired number of generations.

In treating such data, the degree of confidence which can be placed in the figure for litter size must be considered. Its accuracy depends on the carefulness and honesty of the breeder, the accuracy of the clerks in the registry office, and the freedom from typographical errors in the printing of the volume. The matter of personal integrity can be accepted to a high degree, for fortunately the majority of breeders are quite reliable. Whenever falsification wittingly occurs, the tendency is to raise the number per litter; but, owing to the publicity involved in pure-bred breeding as well as the personality invested in breeding animals due to the registry systems, it is doubtful if litter sizes are ever exaggerated by more than one or two pigs.

Investigations in color discrepancies, mistakes in parentage, etc., have shown that about 2 per cent of errors are involved in the work of registry-office clerks and in printing. Some associations are more careful than others, but, of course, none are absolutely free from errors. Unfortunately swine books show a relatively greater number of mistakes than do those published by breeders of some of the other classes of live stock.

However, assuming, as has been done, that the bulk of the records can be accepted, there still remains a question as to their genetic value. It is doubtful whether a sow will ever exceed her hereditary possibilities in number per litter, but there are many forces that may cause her to fall short of that number. Lack of proper nutrition, failure to have all ova released or fertilized, loss of ova, atrophy of fertilized ova or embryos, and disease may all operate against the complete realization of the hereditary make-up. The age at which a sow farrows, the number of litters she has per year, and certain other environmental conditions may also reduce the litter size. It is interesting to observe that this source of error operates in a compensating direction to that of record falsification, when such exists, and in the end the two may counterbalance, although these physiological and pathological factors operate more often than does the misrepresentation of litter numbers.

After admitting all of these sources of error, but hoping that enough records are made under natural conditions to give the figures an investigational value, there still remains the big question of the geneticist, Does the somatic expression of the character indicate the germinal (zygotic) condition of the individual? In other words, Does the fact that a pig is farrowed in a litter of eight indicate that it will transmit a tendency to produce litters of eight? The answer very evidently is No, and the greater the degree of outcrossing in the ancestral lines, the less reliable an index of heredity the size of litter is. Yet it is the only single index obtainable in the study of herdbook records; so for the present it will have to be accepted for what it is worth.

ADVANTAGES OF LITTER SIZE INHERITANCE STUDIES

Accepting the figures for litter size as reasonably representative of the hereditary constitution, there are a number of reasons that make them desirable material for inheritance studies. The most important of these is the fact that the male mated to a female probably does not affect the number at a birth. Instead the size of litters a sow produces represents the segregation of the tendencies transmitted to her by her father and mother. Suppose a sow produces a litter of four pigs and is herself from a litter of seven, the seven does not determine in any way the four, but instead the segregation of some tendency transmitted by her sire or dam is represented. The only check available on this tendency in her sire is the size of litter in which he was farrowed, while the same holds for the dam, except that her own breeding performance may give an additional idea.

METHOD OF RECORDING THE DATA

The data on the animals studied were recorded as follows, the figures representing the size of litters in which the individuals were farrowed:

		Grandsire
		4
Animal	Dam	
4	7	Grandam
		9

The size of litters produced by sows whose sires came from litters of four and whose dams came from litters of seven should give an idea (through the variations recorded) of the hereditary factors involved. It is admissible that all grandams or all grandsires farrowed in the same size of litters may be different in hereditary make-up, but there should be enough individuals alike to make the frequency curves at least suggestive. For convenience, the grandparental generation will be lettered "P," the parental generation "F_1," and the filial generation "F_2," although it is clearly to be understood that this notation does not have the regular Mendelian significance.

DEVIATIONS PER GENERATION

The mean size of 1,770 litters in the P generation was 7.84 ± 0.3494. The standard deviation was 2.18 ± 0.2461. This gives a coefficient of variability of 27.80 for this generation.

The mean size of 885 litters for the F_1 generation was 7.82 ± 0.4897. The corresponding standard deviation was 2.16 ± 0.3462. The coefficient of variability here involved was 27.60, practically the same as that of the grandparental generation.

The mean size of 885 litters in the F_2 generation was 7.91 ± 0.4965, while the deviation was 2.19 ± 0.3511, giving a coefficient of variability of 27.55. (See Table I.)

TABLE I.—*Deviation in size of litters in swine*

Generation.	Number of litters.	Mean.	Standard deviation.	Coefficient of variability.
P	1,770	7.84±0.3494	2.18±0.2461	27.80
F_1	885	7.82± .4897	2.16± .3462	27.60
F_2	885	7.91± .4965	2.19± .3511	27.55

The mean litter size is quite constant from generation to generation, and furthermore quite close to that obtained by Surface (26) for the breed in general. If anything of Mendelism is involved here, it is not revealed by this method of treatment, for the standard deviation is so nearly the same for each of the generations involved as to give no hint of segregation. In fact, the coefficients of variability would indicate a slowly increasing degree of homozygosis.

Two interpretations may be placed on these figures. The animals studied are either practically constant from a zygotic standpoint, and the variations in litter size are due to environmental treatment, or else there is so much heterozygosis present in the grandparents that the parents are as much F_2 as F_1 in hereditary make-up. For the present the writers are going to use the latter interpretation, as there is no evidence at hand to support a belief in the former.

TABLE II.—*Deviation in litter size of the offspring from the parental generation in swine*

Size of litter of parents.		Number of matings.	F_1 generation.		F_2 generation.	
Boar.	Sow.		Mean.	Standard deviation.	Mean.	Standard deviation.
BOAR 1						
1	9	1	5	0	9	0
1	4	1	2	0	9	0
BOAR 2						
2	5	1	4	0	6	0
2	6	2	8 ±1.43	3 ±1.0117	7.5 ±0.239	.5 ±0.1686
2	8	2	6.5 ± .717	1.5 ± .1737	4 ± .479	1 ± .3372
2	9	1	6	0	6	0
BOAR 3						
3	4	3	7 ±0.171	1.41±0.3433	9 ±1.704	4.32±1.194
3	6	2	6.5 ± .239	.5 ± .1686	8 ± .95	2 ± .674
3	7	4	7.25±1.6218	4.8 ±1.1502	7.75± .8869	2.63± .627
3	11	1	6	0	8	0
3	10	2	10 ± .95	2 ± .674	11	0
3	14	1	11	0	6	0

TABLE II.—*Deviation in litter size of the offspring from the parental generation in swine*—Continued

BOAR 4

Size of litter of parents.		Number of matings.	F_1 generation.		F_2 generation.	
Boar.	Sow.		Mean.	Standard deviation.	Mean.	Standard deviation.
4	3	1	8	0	5	0
4	4	3	7.66±1.032	2.62±0.723	8 ±0.631	1.63±0.442
4	5	5	7.2 ± .9951	3.29± .7022	7.6 ± .5202	1.72± .3671
4	6	7	8 ± .2887	1.13± .2037	7.14± .2836	1.11± .2001
4	7	8	8.5 ± .6863	2.42± .408	5.87± .2726	1.14± .1922
4	8	6	7.83± .5390	1.95± .3801	6.83± .7712	2.79± .5438
4	9	6	7.16± .8127	2.94± .5731	7.33± .4008	1.45± .2826
4	10	4	7.25± .5092	1.51± .3618	6.75± .3844	1.14± .2012
4	12	1	7	0	12	0

BOAR 5

5	3	1	6	0	12	0
5	4	4	5.75±0.6407	1.92±0.4543	6.5 ±0.3743	1.11±0.2654
5	5	3	7 ± .3195	.81± .2239	6.66± .6666	1.69± .4671
5	6	14	8 ± .3228	1.79± .2282	7.21± .1531	.85± .1083
5	7	12	7.91± .4464	2.29± .358	7.66± .3099	1.59± .2193
5	8	16	7.37± .3979	2.36± .2817	7.56± .408	2.42± .2889
5	9	9	8.11± .3844	1.71± .272	8.22± .5866	2.61± .415
5	10	6	9.33± .5943	2.15± .4191	8.66± .3759	1.36± .2651
5	11	3	6.66± .4891	1.24± .3427	8.33± .3707	.94± .2598
5	12	2	4	0	9	0

BOAR 6

6	2	1	7	0	8	0
6	3	3	7.66±0.8283	2.1 ±0.5805	3.33±0.6243	1.58±0.4367
6	4	3	4.66±1.1161	2.83± .7822	9.33± .4391	1.24± .3426
6	5	6	8.6 ± .6041	2 ± .4267	6.83± .4533	1.64± .3197
6	6	11	6.72± .4604	2.26± .3251	8.9 ± .4625	2.27± .3263
6	7	18	7.05± .2672	1.68± .1888	8.5 ± .252	1.86± .178
6	8	24	7.58± .3255	2.36± .2300	7.46± .1862	1.35± .1315
6	9	15	8.4 ± .0046	2.74± .0311	8 ± .047	2.7 ± .0314
6	10	8	6.62± .4657	1.71± .2885	7.87± .6075	2.54± .4283
6	11	5	9 ± .9151	2.32± .6414	5 ± .6922	2.29± .4887
6	12	3	7.66± .1853	.47± .1299	8.33±1.136	2.88± .796

BOAR 7

7	3	1	6	0	10	0
7	4	4	7.5 ±0.8431	2.5 ±0.5802	8.5 ±0.1631	5 ±0.119
7	5	7	7.71± .4202	1.62± .292	7.85± .6106	2.39± .431
7	6	17	7.25± .2177	1.33± .1541	7.58± .239	1.46± .1691
7	7	19	7.52± .3023	1.95± .2135	7.42± .3178	2.05± .2244
7	8	26	8.03± .3637	1.99± .1843	7.8 ± .2545	1.92± .1778
7	9	41	9.29± .1958	1.83± .1363	8.82± .2077	1.94± .1445
7	10	8	8.37± .5333	2.23± .3760	6.62± .4616	1.93± .3254
7	11	16	8.5 ± .2596	1.54± .1838	8.43± .4502	2.76± .3187
7	12	6	8.66± .5943	2.15± .4191	6.5 ± .6109	2.21± .4302
7	13	1	10	0	4	0

TABLE II.—*Deviation in litter size of the offspring from the parental generation in swine*—Continued

BOAR 8

Size of litter of parents.		Number of matings.	F_1 generation.		F_2 generation.	
Boar.	Sow.		Mean.	Standard deviation.	Mean.	Standard deviation.
8	3	7	7.28±0.1124	0.44±0.0793	7 ±0.3193	1.25±0.2254
8	4	8	8.75± .6721	2.81± .4738	7.75± .5572	2.33± .3928
8	5	11	7.33± .2634	1.91± .1861	8.27± .6377	3.13± .4501
8	6	24	6.91± .2965	2.15± .2094	7.66± .3062	2.22± .2161
8	7	29	7.86± .2394	1.91± .1692	7.82± .277	2.21± .1958
8	8	43	6.58± .2519	2.45± .1783	7.23± .2076	2.02± .1469
8	9	34	8.14± .292	2.52± .2124	8.17± .2294	1.98± .1669
8	10	10	6.7 ± .2219	1.04± .1565	8.4 ± .1462	5.37± .8083
8	11	10	7.8 ±1.024	4.8 ± .7225	8.6 ± .512	2.4 ± .3612
8	12	3	9 ±1.4061	3.55± .9895	9.66± .8415	2.04± .5639
8	13	1	9	0	10	0
BOAR 9						
9	2	1	5	0	9	0
9	3	1	5	0	7	0
9	4	6	7.83±0.4616	1.67±0.3254	7.66±0.4616	2.05±0.3996
9	5	12	7.5 ± .3898	2 ± .2758	6.91± .4482	2.3 ± .3172
9	6	7	6.71± .4444	1.74± .3138	7.14± .6065	2.35± .4238
9	7	32	7.59± .2232	1.87± .1576	8.53± .2495	2.09± .1762
9	8	26	7 ± .2663	2.01± .1861	7.5 ± .3074	2.32± .2148
9	9	35	7 ± .3172	2.95± .2377	8.71± .2158	2.10± .1693
9	10	14	8.66± .4060	2.33± .2874	7.53± .3468	1.99± .2453
9	11	8	7.75± .409	1.71± .2883	8.5 ± .526	2.2 ± .3709
9	12	4	8 ± .1686	.5 ± .119	9.25± .3709	1.1 ± .263
9	13	1	7	0	8	0
9	15	1	6	0	8	0
BOAR 10						
10	1	1	8	0	14	0
10	3	2	9 ±0.4784	1 ±0.3372	7.5 ±1.674	3.5 ±1.1803
10	4	2	9	0	7.5 ±1.674	3.5 ±1.1803
10	5	4	7 ± .4755	1.41± .3372	7.25± .4957	1.47± .3516
10	6	6	7.66± .34	1.23± .2397	8 ± .3897	1.41± .2749
10	7	16	7.93± .3591	2.13± .2542	8.18± .4991	2.96± .3533
10	8	24	8.29± .2978	2.16± .2105	8.26± .3787	2.69± .2676
10	9	11	8.9 ± .6153	3.02± .4343	8.63± .3586	1.76± .2531
10	10	14	6.78± .4128	2.29± .2919	7.57± .2777	1.54± .1963
10	11	4	8.25± .435	1.29± .3085	9.5 ± .5598	1.66± .397
10	12	6	8.5 ± .525	1.9 ± .370	8.63± .5888	2.13± .4151
10	14	1	10	0	8	0
BOAR 11						
11	3	1	9	0	10	0
11	4	1	6	0	9	0
11	5	5	6.8 ±0.0574	1.9 ±0.0405	8.2 ±0.5111	1.69 ±0.3607
11	6	6	8 ± .5749	2.08± .4054	6.33± .4644	1.68 ± .3275
11	7	12	7.33± .3004	1.54± .2124	7.85± .3804	2.007± .2705
11	8	4	8.5 ± .1686	.5 ± .1190	8.75±1.2107	3.59 ± .8586
11	9	6	8.83± .6053	2.19± .4269	8.16± .4809	1.74 ± .3391
11	10	6	7.5 ± .3434	1.25± .2422	8.66± .4646	1.69 ± .3277
11	13	1	6	0	12	0
11	15	1	9	0	9	0

TABLE II.—*Deviation in litter size of the offspring from the parental generation in swine*—Continued

BOAR 12

Size of litter of parents.		Number of matings.	F_1 generation.		F_2 generation.	
Boar.	Sow.		Mean.	Standard deviation.	Mean.	Standard deviation.
12	2	1	9	0	7	0
12	4	2	9.5 ± 0.238	.5 ±0.118	8.5 ± 0.238	.5 ±0.118
12	5	2	4 ± .956	2 ± .6745	7	0
12	6	1	8	0	10	0
12	7	5	7.6 ± .554	1.85± .3001	9.2 ± .399	1.32± .282
12	8	6	8.82± .384	1.39± .27	8.5 ± .671	2.4 ± .473
12	9	6	6.5 ± .591	2.14± .414	7.83± .387	1.4 ± .272
12	10	1	11	0	10	0
12	11	2	11	0	8.5 ± .717	1.5 ± .505
12	12	1	10	0	12	0
12	13	2	7	0	9.5 ± .717	1.5 ± .505

BOAR 13

13	6	3	8.66± 0.493	1.25±0.345	8.33± 0.185	0.47±0.129
13	8	2	9.5 ± .717	1.5 ± .505	7 ± .956	2 ± .6745
13	9	2	11.5 ± .717	1.5 ± .505	9 ± .956	2 ± .6745
13	11	1	10	0	6	0
13	12	2	7.5 ± .168	.5 ± .245	10 ± .479	1 ± .337
13	13	5	9.6 ± .526	1.74± .371	10 ± .956	2 ± .6745

BOAR 14

14	8	2	9	0	10.5 ± 0.239	0.25±0.1686
14	9	1	9	0	11	0
14	12	1	7	0	3	0

BOAR 15

15	8	1	12	0	8	0

INDIVIDUAL EVIDENCES OF SEGREGATION

Table II is produced by treating the litter size as a detailed character and comparing the parental generation with offspring. The average of the F_1 deviations is 1.87±0.0549, while the F_2 mean deviation is 1.92± 0.0582. The probable errors make these two constants overlap, so that the individual treatment when lumped seems no more significant than when the deviations per generation are considered. Yet many individual evidences of segregation exist, and many times the F_2 generation from a particular cross is so small in numbers that only a fragmentary view of the segregable possibilities is obtained.

While it is possible that 90 per cent of the litter sizes in these tables do not represent the exact genetic constitution, yet it is probable that in general the greater the disparity in litter sizes between the two animals in the P generation, the greater will be the expected deviations in the F_2, and the smaller the deviations in the F_1 generation. The following results, Table III, are produced by tabulating the averages of the deviations on this basis.

TABLE III.—*Average deviations in litter size in the F_1 and F_2 generations of swine*

Difference in number of pigs in the two P litters.	0	1	2	3	4	5	6	7	8
F_1 deviations	2. 13	1. 89	1. 93	2. 04	2. 19	1. 82	1. 32	1. 12	0. 5
F_2 deviations	1. 91	1. 84	2. 16	2. 10	2. 16	1. 71	1. 72	1. 98	. 5

A calculation of the probable errors involved in this table shows that only the difference between the F_1 and F_2 deviations where the disparity in litter size is seven pigs is large enough to be mathematically significant. The difference when the parents vary from each other by two pigs and by six pigs is on the border line between significance and nonsignificance, but the five other columns are distinctly unenlightening. Yet, if the difference of two pigs is barred, the results are what might be expected.

One criticism against the preceding method of treatment is thoroughly valid. If swine fertility depends on only one or two genetic factors, it is obvious that the point at which the difference between the two parents occurs is more important than the degree of difference. For example, if there is a physiological division point between two hereditary factors at six pigs, then a difference of two or even of four below six pigs might not be significant, while a difference of one more or one less in a litter of six or seven pigs would be thoroughly significant. An examination of the data from this point of view is now in progress, but it is probable that the key to the situation will only be discovered by breeding experiments.

CURVES OF LITTER FREQUENCIES

The distribution of the different sizes of litters in the three generations is given in Table IV.

TABLE IV.—*Litter frequencies in swine*

Generation.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
P	Expected	0. 11	1. 5	9. 8	39	108	216	324	370	324	216	108	39	9. 8	1. 5	0. 11
	Actual	3	9	30	80	124	198	300	362	318	162	91	59	26	6	3
F_1	Expected	. 05	. 75	4. 9	19	54	108	162	185	162	108	54	19	4. 9	. 75	. 05
	Actual	0	5	14	32	69	122	149	161	149	85	62	23	8	4	2
F_2	Expected	. 05	. 75	4. 9	19	54	108	162	185	162	108	54	19	4. 9	. 75	. 05
	Actual	0	4	17	32	63	107	154	172	135	95	59	30	11	3	3

Figures 1, 2, 3, and 4 show the curves for the litter frequencies in the three generations and indicate how close the actual numbers of litters come to the binomial curve $(x+y)^{14}$. It is perhaps incorrect to call the theoretical frequencies recorded in Table IV "expectations," unless it is clearly understood that they are the expectations founded on the nearest binomial. There is nothing in the inheritance to make them true expectations from an experimental standpoint.

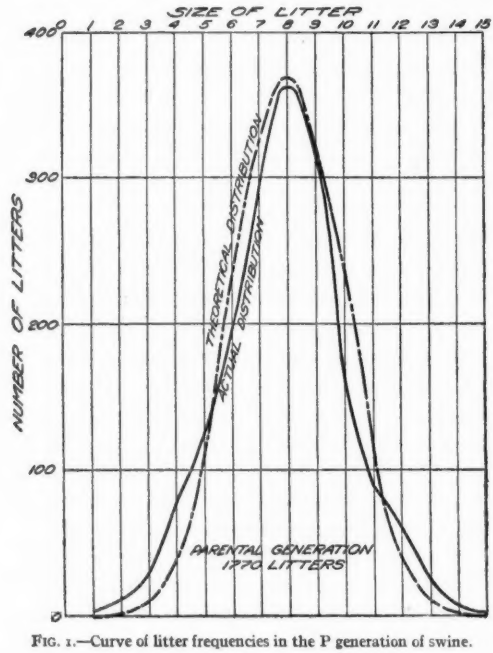


FIG. 1.—Curve of litter frequencies in the P generation of swine.

The curve of the actual distribution spreads out at the extremities much wider than should be expected on a chance basis. This is true in regard to both extremes of the curve and makes it appear as though the curve were compound—i. e., the sum of several curves having separate means from which deviations take place. An analysis on this basis gives two small curves at the extremes, which, while they do not give perfect Gaussian distributions, are characteristic enough to make the assumption of another mean for each perfectly valid. The modes of these three curves are as follows:

Curve 1	4 pigs per litter.
Curve 2	8 pigs per litter.
Curve 3	12 pigs per litter.

It is premature to announce that these modes represent centers of deviation for genetic factors, although a casual observation of the individual data makes it seem that this condition may exist. Furthermore, the mode of curve 1 corresponds to the degree of fertility which Simpson states is characteristic of the wild hog, while the mode of curve 3 is very close to that of the Tamworth, the most fecund of domestic breeds. This indicates that the two may represent basic and improved factors for fertility, respectively, while curve 2 represents heterozygous conditions.

Before these curves can be accepted as more than merely suggestive a further analysis must be made. There is a significant deviation from expectancy in the right-hand branch of the curve of the total population, which persists even after the separation into three curves. In figure 4 this deficiency is located in the left-hand branch of curve 3, but the minus deviations may just as logically belong in the right-hand branch of curve 2, suggesting that it also may be compounded of two curves dependent on a genetic factor not disclosed thus far.

Paralleling this study some actual matings of swine have been planned and are in progress.

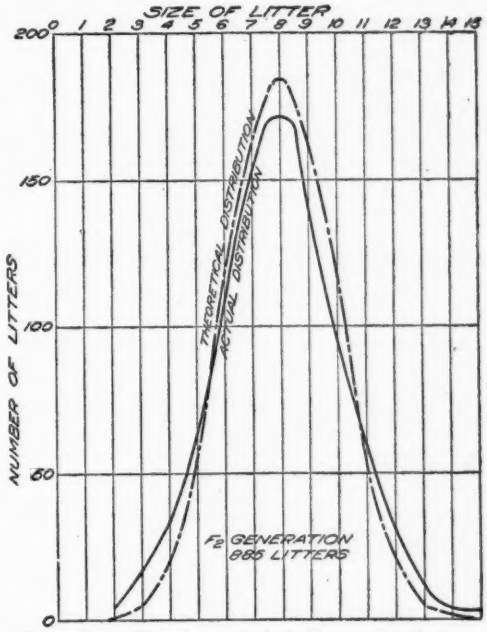


FIG. 2.—Curve of litter frequencies in the F_1g eneration of swine.

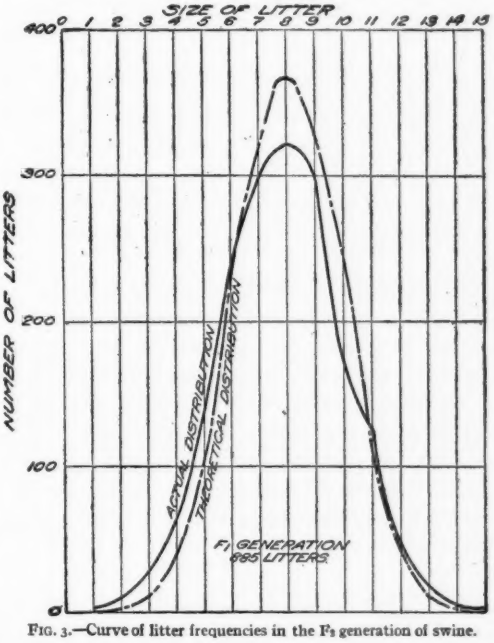


FIG. 3.—Curve of litter frequencies in the F_2 generation of swine.

SUMMARY

(1) Fertility in swine offers favorable material for the study of quantitative inheritance, because the units of deviation are discrete.

(2) Biometric studies of litter size with mother and daughter have indicated a small degree of inheritance.

(3) Crosses of breeds having different mean

litter sizes have suggested that segregations of fecundity factors may take place.

(4) Numerous nongenetic factors limit the full expression of the inborn possibilities of fertility.

(5) Certain few somatic characters may be correlated either in a physiological or genetic manner with the different degrees of fecundity, but the bulk of characters usually assumed to be so related are probably entirely independent of it.

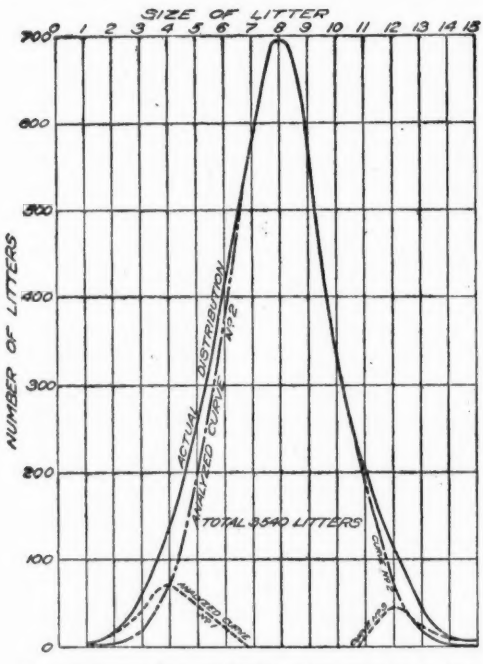


FIG. 4.—Diagram of the combined litter frequencies for the three generations of swine analyzed into its component curves.

(6) Herdbook data on the fertility of swine present sources of error, but the percentage of error is low enough to permit the statistics to be suggestive.

(7) Numerous influences exist which lower the size of litter, which sources of error may operate in a manner compensatory to those just mentioned.

(8) It is questionable whether the size of litter represents the hereditary factors transmitted, but the somatic character was perforce accepted at face value in these studies.

(9) There is no reduction in variability in the litter sizes of the dams as compared with the grandparents or progeny, as would result if there were homozygous differences for fertility in the grandparents. Hence, the fertility deviations are either nongerminal or else the degree of heterozygosis is so great in the grandparents that no increased variability in the F_2 generation is possible. The latter explanation is probably the correct one.

(10) The frequency curves for the 3,540 litters studied make it appear that there are at least three centers of deviation in swine fertility. These centers possibly correspond to genetic factors involved in the inheritance of fecundity.

LITERATURE CITED

(1) BITTING, A. W.
1898. The fecundity of swine. *In* 10th Ann. Rpt. Ind. Agr. Exp. Sta. 1897, p. 42–46.

(2) CASTLE, W. E., and PHILLIPS, J. C.
1914. Piebald Rats and Selection; an Experimental Test of the Effectiveness of Selection and of the Theory of Gametic Purity in Mendelian Crosses. 56 p., 3 pl. Washington, D. C. (Carnegie Inst. Washington Pub. 195.) Bibliography, p. 31.

(3) DETLEFSEN, J. A.
1914. Genetic Studies on a Cavy Species Cross. 134 p., 10 pl. (1 col.). Washington, D. C. (Carnegie Inst. Washington Pub. 205.) Bibliography, p. 129–132.

(4) EVVARD, J. M.
1912. Nutrition as a factor in fetal development. *In* Ann. Rpt. Amer. Breeders' Assoc., v. 8, p. 549–560.

(5) ———
1913. Some factors affecting fetal development. *In* Proc. Iowa Acad. Sci., v. 20, p. 325–330.

(6) GEORGE, C. R.
1912. The inheritance of fecundity in Poland-China swine. Thesis, University of Ohio.

(7) GOLDSCHMIDT, Richard.
1913. Zuchtversuche mit Enten I. *In* Ztschr. Indukt. Abstamm. u. Vererbungslehre, Bd. 9, Heft 3, p. 161–191.

(8) HAMMOND, John.
1914. On some factors controlling fertility in domestic animals. *In* Jour. Agr. Sci., v. 6, pt. 3, p. 263–277, pl. 3.

(9) LEWIS, L. L.
1911. The vitality of reproductive cells. Okla. Agr. Exp. Sta. Bul. 96, 47 p., 7 fig.

(10) MACDOWELL, E. C., and CASTLE, W. E.
1914. Size Inheritance in Rabbits . . . with a Prefatory Note and Appendix, by W. E. Castle. 55 p., illus. Washington, D. C. (Carnegie Inst. Washington Pub. 196.) Bibliography, p. 47–49.

(11) MCMURRICH, J. P.
1913. Development of the Human Body . . . ed. 4, 495 p., 285 fig. Philadelphia.
Cites (p. 35) case reported by Dührssen.

(12) MARSHALL, F. H. A.
1908. Fertility in Scottish sheep. *In* Trans. Highland and Agr. Soc. Scot., s. 5, v. 20, p. 139–151.

(13) ———
1910. The Physiology of Reproduction . . . with a Preface by E. A. Schäfer . . . and Contributions by William Cramer . . . and James Lochhead. 706 p. illus. New York, London.

(14) PARKER, G. H., and BULLARD, C.
1913. On the size of litters and the number of nipples in swine. Proc. Amer. Acad. Arts and Sci., v. 49, no. 7, p. 397–426. Bibliography, p. 413.

(15) PEARL, Raymond.
1912. The mode of inheritance of fecundity in the domestic fowl. *In* Jour. Exp. Zool., v. 13, no. 2, p. 153–268, 2 fig. Literature cited, p. 266–268.

(16) PEARL, Raymond.
1913. On the correlation between the number of mammæ of the dam and size of litter in mammals. I. Interracial correlation. *In* Proc. Soc. Exp. Biol. and Med., v. 11, no. 1, p. 27–30.

(17) ———
1913. On the correlation between the number of mammæ of the dam and size of litter in mammals. II. Intraracial correlation in swine. *In* Proc. Soc. Exp. Biol. and Med., v. 11, no. 1, p. 31–32.

(18) PEARSON, Karl, LEE, Alice, and BRAMLEY-MOORE, Leslie.
1899. Mathematical contributions to the theory of evolution. VI. Genetic (reproductive) selection: Inheritance of fertility in man, and of fecundity in thoroughbred racehorses. *In* Phil. Trans. Roy. Soc. London, s. A, v. 192, p. 257–330.

(19) PHILLIPS, J. C.
1912. Size inheritance in ducks. *In* Jour. Exp. Zool., v. 12, no. 3, p. 369–380. Bibliography, p. 380.

(10) ———
1914. A further study of size inheritance in ducks with observations on the sex ratio of hybrid birds. *In* Jour. Exp. Zool., v. 16, no. 1, p. 131–148. Bibliography, p. 145.

(21) PUNNETT, R. C., and BAILEY, P. G.
1914. On inheritance of weight in poultry. *In* Jour. Genetics, v. 4, no. 1, p. 23–39, 2 fig., pl. 4.

(22) ROMMELL, G. M.
1906. The fecundity of Poland-China and Duroc-Jersey sows. U. S. Dept. Agr. Bur. Anim. Indus. Circ. 95, 12 p.

(23) ———
1907. The inheritance of size of litter in Poland China sows. *In* Amer. Breeders' Assoc. Rpt. v. 3, p. 201–208.

(24) ——— and PHILLIPS, E. F.
1906. Inheritance in the female line of size of litter in Poland China sows. *In* Proc. Amer. Phil. Soc., v. 45, no. 184, 245–254. Bibliography, p. 254.

(25) SIMPSON, Q. I.
1912. Fecundity in swine. *In* Ann. Rpt. Amer. Breeders' Assoc., v. 7, p. 261–266.

(26) SURFACE, F. M.
1909. Fecundity of swine. *In* Biometrika, v. 6, pt. 4, p. 433–436.

RELATION OF GREEN MANURES TO THE FAILURE OF CERTAIN SEEDLINGS

By E. B. FRED,

Agricultural Bacteriologist, Agricultural Experiment Station of the University of Wisconsin[1]

INTRODUCTION

In a previous report it has been shown that if green manures are turned under and the soil planted immediately, a decrease in germination may result. For example, a 20-acre field, half in crimson clover (*Trifolium incarnatum*) and half in fallow, was plowed and planted to cotton (*Gossypium* spp.) (17, p. 26).[2] On the crimson-clover plot the cotton failed almost completely to germinate. Here and there a few crippled seedlings appeared, while on the fallowed plot normal germination occurred. Seed from the same lot was used on both plots. The green manure in some way seriously affected the germination of the cottonseed. Three weeks later the green-manure plot was again seeded to cotton. Germination at this time was perfectly normal. Apparently the harmful factor disappeared during the interval of three weeks.

A more extensive study of the substances affecting seed germination and of the factors involved was deemed advisable. The controlling idea in this investigation was a study of the effect of green manures on the germination of different seeds. In determining the percentage of germination, only those seedlings that appeared above the surface are recorded.

The amount of green manure used was determined from the following calculation: A good crop of clover should yield from 4 to 5 tons of undried green hay per acre. If 1 acre of soil 3 inches deep weighs 1,000,000 pounds, then 1 per cent of green clover is comparable to the amount employed under field conditions. Except in rare cases this amount of green manure was used in all of the laboratory studies. The green plant tissue was cut just before blooms began to form, finely chopped, and mixed thoroughly with Miami silt loam soil from the Experiment Station farm. The soil moisture was maintained at 50 per cent saturation. All tests of germination are recorded in percentages. Photographs were made of the young seedlings two weeks after planting.

EFFECT OF GREEN MANURES ON THE GERMINATION OF VARIOUS SEEDS

Since it has been shown that seeds of different plants vary widely in chemical composition, it is very probable that they will react differently toward green manures. This experiment was planned to test the effect

[1] Published with the permission of the Director of the Wisconsin Agricultural Experiment Station.

[2] Reference is made by number to "Literature cited," p. 1175-1176.

Journal of Agricultural Research,
Dept. of Agriculture, Washington, D. C.
ct

Vol. V, No. 25
Mar. 20, 1916
Wis.—4

27467°—16——2

of decomposing plant tissue on the germination of buckwheat, castor beans, corn, crimson clover, flax, hemp, lupines, mustard, oats, peanuts, soybeans, sunflower, and wheat. The percentage composition of these seeds is given in Table I.

TABLE I.—*The percentage composition of various seeds (11, 20)*

Name.	Fat.	Crude protein.	Nitrogen-free extract.	Crude fiber.	Ash.
Castor bean (*Ricinus communis*)	51.37	18.75	1.5	18.1	3.1
Peanut (*Arachis hypogaea*)	45	25	18	.....	2 to 5
Flax (*Linum usitatissimum*)	33.7	22.6	23.2	7.1	4.3
Hemp (*Cannabis sativa*)	32.58	18.23	21.06	14.97	4.24
White mustard (*Brassica alba*)	29.66	27.59	20.83	10.27	4.47
Sunflower (*Helianthus annuus*)	28.79	16.3	17.28	27.9	3.3
Cotton (*Gossypium herbaceum*)	20.86	19.69	23.43	21.1	3.8
Soybean (*Glycine soja*)	17.00	35.00	26.00	5 to 6	4.5
White lupine (*Lupinus albus*)	6.79	28.78	33.65	11.92	2.99
Oat (*Avena sativa*)	5.27	10.25	59.68	9.97	3.02
Corn (*Zea mays*)	4.5	9.5	68.5	2.18	1.6
Buckwheat (*Fagopyrum tataricum*)	2.68	11.41	58.79	11.44	2.38
Wheat (*Triticum sativum*)	1.65	10.93	70.01	2.12	1.92

The seeds are grouped according to fat content; those richest in fat are given first. The marked difference in the chemical composition of various seeds is very noticeable. For instance, castor beans contain more than 50 per cent of fat, while oats contain less than 2 per cent.

According to Nobbe (16, p. 173), seeds rich in oil require more oxygen for germination than starch seeds. In Tables II, III, and IV data are presented concerning the effect of green manures on various seeds. In every case the seeds were tested under identical conditions. The figures of Table II show the effect of 1 per cent of green clover on the germination of buckwheat, corn, hemp, lupine, and sunflower.

TABLE II.—*Effect of green clover on the germination of various seeds*

No.	Seed.	Treatment.	Germination.		
			1 week.	2 weeks.	Relative.
			Per cent.	*Per cent.*	*Per cent.*
1	Buckwheat	None	75	90	100
2	.....do	1 per cent clover	90	90	100
3	Corn	None	100	100	100
4	.....do	1 per cent clover	95	100	100
5	Hemp	None	95	95	100
6	.....do	1 per cent clover	65	65	68
7	Lupine	None	75	80	100
8	.....do	1 per cent clover	60	60	75
9	Mustard	None	95	95	100
10	.....do	1 per cent clover	55	55	58
11	Sunflower	None	90	90	100
12	.....do	1 per cent clover	90	90	100

The average percentage of germination in duplicate pots, after one and two weeks, is recorded in Table II. The last column gives the relation between the treated and untreated seeds. A glance at the figures shows clearly that buckwheat, corn, and sunflower were not injured by green manures. On the other hand, hemp and mustard were seriously injured; the latter showed the greatest loss. Lupines are not so sensitive as mustard or hemp toward green manure, although a slight decrease in germination is noted.

As regards fat content, it will be seen that with the exception of sunflower those seeds rich in oil are the most sensitive to green manuring. The very quick germination of sunflower seed may explain their resistance to the injurious factor.

Table III presents data to show the striking difference in behavior of fat and starch seeds toward green manures. A comparison of the injury resulting from the use of green clover and green oats is made.

TABLE III.—*Effect of green clover and oats on the germination of cottonseed and wheat*

No.	Seed.	Treatment.	Germination.			
			1 week.	2 weeks.	3 weeks.	Relative.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	Cotton.....	None.....	85	92. 5	92. 5	100
2	.....do.....	1 per cent of oats.....	45	65	65	70
3	.....do.....	1 per cent of clover..	17. 5	17. 5	17. 5	19
4	Wheat.....	None.....	95	100	100	100
5	.....do.....	1 per cent of oats.....	85	90	90	90
6	.....do.....	1 per cent of clover..	85	85	85	85

The germination of cotton was seriously injured by the presence of green manures; the green clover was much more harmful than oat tissue. Wheat was little affected by the use of green manure. The data confirm the results of the preceding test—that is, that seeds rich in oil are especially sensitive to green manures. It appears that the percentage of injury depends to a certain degree on the source of the plant tissue. Plate LXXXIII, figure 1, is reproduced from a photograph of cotton seedlings two weeks after planting. In order to make the seedlings more visible, a thin layer of white quartz sand was poured upon the surface of the soil.

With soybeans in place of wheat, this experiment was repeated, as shown in Table IV.

TABLE IV.—*Effect of green clover and oats on the germination of cottonseed and soybeans*

No.	Seed.	Treatment.	Germination.			
			1 week.	2 weeks.	3 weeks.	Relative.
			Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	Cotton....	None.....	95	100	100	100
2	.....do.....	1 per cent of oats.....	35	35	35	35
3	.....do.....	1 per cent of clover..	.....	10	10	10
4	Soybean...	None.....	100	100	100	100
5	.....do.....	1 per cent of oats	40	40	40	40
6	.....do.....	1 per cent of clover..	30	60	60	60

Here it was again found that the oil seeds are very sensitive to green-manuring. Soybeans are more resistant to this injury than cotton.

As regards the source of the green manure, the results of numerous tests indicate that clover causes a greater loss than oat tissue. An exception to this is found with soybeans (Table IV). No satisfactory explanation has been found for the different action of these two substances. The average of three total-nitrogen analyses shows that clover contains 80.27 per cent of moisture and 4.8 per cent of protein (dry basis). The oats contained 82 per cent of moisture and 3.96 per cent of protein. Chemical analyses fail to disclose any very striking differences between the clover and oat tissue. Indeed, the protein content is nearly the same in both substances. It is possible that the nitrogen of legumes is more available than that of nonlegumes (14). It was noticed repeatedly that clover tissue decomposes more rapidly than oat tissue.

EFFECT OF TIME OF PLANTING AND QUANTITY OF GREEN MANURE ON THE GERMINATION OF COTTON SEED

Ten half-gallon jars were filled with soil and treated as shown in Table V.

TABLE V.—*Effect of time of planting and quantity of clover on the germination of cottonseed*

No.	Treatment.	Germination.							
		Planted immediately.				Planted two weeks later.			
		1 week.	2 weeks.	3 weeks.	Relative.	1 week.	2 weeks.	3 weeks.	Relative.
		Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	None.....	90	90	90	100	90	95	95	100
2	0.25 per cent of clover..	60	60	60	66	90	95	95	100
3	0.5 per cent of clover...	50	50	50	55	80	95	95	100
4	1.0 per cent of clover...	35	35	35	38	100	100	100	100
5	2.0 per cent of clover...	.....	.....	.....	.....	75	85	85	89
6	3.0 per cent of clover...	.....	.....	.....	.....	70	85	85	89

From the data of this experiment it is very evident that the serious injury caused by green manures is only temporary. Two weeks after the green manure was turned under, the conditions that affect seed germination disappeared. Aside from the temporary nature of the injurious agent, it will be seen that the percentage of injury is fairly proportionate to the amount of green clover used. In the presence of 0.25 per cent, the rate of germination was decreased 34 per cent, while more than 1 per cent of green manure entirely prevented germination. A comparison of the effect of green manures in different stages of decomposition on cotton germination is shown in Plate LXXXIII, figures 2 and 3.

FIELD EXPERIMENTS WITH GREEN MANURES

Early in the spring of 1914 a series of plot experiments with various seeds was made. For this purpose a good clover sod from the Experiment Station farm, near Madison, Wis., was chosen. This sod was divided into three equal sections: *A*, Clover; *B*, oats; and *C*, unplanted. The sections were subdivided into six plots, as shown in Table VI. Section *A* was allowed to remain in clover, while *B* and *C* were plowed, section *B* planted to oats, and *C* left without any crop. When the oats in section *B* and the clover in section *A* were partly in bloom, the soil was plowed and prepared for planting. One half of each section was planted immediately, the other half 25 days later. It was arranged to study the effect of clover and oat tissue on the germination of cotton, corn, hemp, oats, and soybeans. The same weight of seed was planted in each plot. The results of this series of tests are given in Tables VI and VII.

TABLE VI.—*Effect of green clover on the germination of various seeds*

No.	Seed.	Planted immediately after turning under.				Germination of seed planted 25 days after turning under.	
		With clover.		Unplanted.		With clover.	Unplanted.
		Seed germination.	Weight.	Seed germination.	Weight.		
			Pounds.		*Pounds.*		
1	Cotton	60	.....	91	.....	190	210
2	.....do	71	.....	129	.....	202	218
3	Corn	76	21	79	27	68	75
4	Hemp	Few.	8	Many.	27	1,050	1,130
5	Oats	505	.....	474	.....	Fine.	Fine.
6	Soybean	58	4	83	5.5	83	88

TABLE VII.—*Effect of oats on the germination of various seeds*

No.	Seed.	Germination of seed.			
		Planted immediately after turning under.		Planted 25 days after turning under.	
		With oats.	Unplanted.	With oats.	Unplanted.
1	Cotton	100	210	134	140
2	....do	117	218	125	131
3	Corn	62	75	72	73
4	Hemp	450	1,130	210	320
5	Oats	Many.	Many.	Many.	Many.
6	Soybean	35	88	39	40

From these tables it will be seen that green manures seriously injure the germination of cotton, soybeans, and hemp, while corn and oats are not affected. The diminished germination is not confined to clover tissue, but is noted with oats. This effect of the plant tissue on germinating seeds is also observed in the weight of harvest. Unfortunately, because of climatic conditions, the cotton could not be grown to maturity. On adjoining plots, where the green manure was allowed to decompose for 25 days before planting, no injury was observed.

The field data show (1) that green manures largely prevent the germination of certain oil seeds, and (2) that the unfavorable condition is only temporary.

NATURE OF THE INJURIOUS AGENT

There are a number of possible causes that might account for the destructive influence of green manures on seed germination:

First, the green manure greatly increases the number and variety of micro-organisms. The organisms on the plant tissue may be harmful, or conditions proper for the development of harmful organisms may arise.

Second, the large gain in number of organisms, after the addition of green manure, results in a possible accumulation of substances toxic to germination—for example, poisonous by-products of decomposition, as alkali or acid.

Third, the rapid multiplication of micro-organisms, which results in an increased metabolism, causes soil oxygen to be consumed and carbon dioxid to be given off. Such loss in oxygen and gain in carbon dioxid might conceivably retard or prevent germination. If it is assumed that oil seeds require more oxygen for germination than starch seeds, the third supposition should apply particularly to seeds rich in fat (16, p. 173).

EFFECT OF SOIL TYPE

In order to ascertain the relation to soil type of the agent causing a decrease in germination, a series of tests was made. Four soil types were used: Colby silt loam, Miami silt loam, Sparta acid sand, and neutral sand. The results of the first test are given in Table VIII.

TABLE VIII.—*Effect of green manure on the germination of cottonseed*

No.	Soil.	Treatment.	Germination.			Relative.
			1 week.	2 weeks.	3 weeks.	
			Per ct.	*Per ct.*	*Per ct.*	*Per ct.*
1	Colby silt loam (acid)	None	90	90	90	100
2	do	1 per cent of clover	35	45	50	55
3	Miami silt loam	None	75	75	75	100
4	do	1 per cent of clover	35	35	35	50
5	Miami silt loam, half sand	None	95	95	95	100
6	do	1 per cent of clover	45	45	45	50
7	Sand	None	80	80	80	100
8	do	1 per cent of clover	90	90	90	112
9	Sparta acid sand	None	80	80	85	100
10	do	1 per cent of clover	70	70	70	82

For the purpose of securing variation in texture, dilutions with Miami soil and quartz sand were made. From the data obtained, it seems that the property of reducing seed germination is common to both silt loams, but is absent or almost inactive in the sands. Since the relative decrease in germination is approximately the same with Miami or Colby silt loam, it appears that soil reaction is not one of the controlling factors. In neutral or acid sand no decided injury was noted. The results of a second series of tests confirm the above statement. Just why sandy soil should prove less efficient than the loams is not evident from the data, unless it is due to the absence of the injurious factor.

EFFECT OF POSITION OF GREEN MANURE

It was arranged to study the effect on seed germination of plant tissue at different depths. Green clover was added at the rate of 1 per cent. The results secured were as follows: When the green manure was placed in the bottom of the jar, 80 per cent of cotton germinated; in the middle, none germinated; on top, 10 per cent germinated. It is evident that green clover must be in close contact with the seed in order to be effective. This may be shown by wrapping cotton seeds with clover leaves. One or two clover leaves greatly injured seed germination. Plate LXXXIII, figure 4, shows the effect of position of green manure on seed germination.

EFFECT OF INCREASED AERATION

In view of the different action of green manures in compact and open soils, it was decided to make a series of tests under conditions that tend to remove gaseous substances. For this purpose, specially designed jars with openings in their bottoms were employed. By means of a glass tube connected with the bottoms of the jars, air was forced through the soil. In these tests air was allowed to pass through the soil for 20 to 30 minutes every day. A comparison of germination in the aerated and unaerated soils failed to show any difference. Change in soil air did not lessen the injury.

EFFECT OF TEMPERATURE

It is a well-known fact that slight changes in temperature often greatly increase or decrease the growth of micro-organisms. Accordingly a test was made with three variations in temperature.

TABLE IX.—*Effect of temperature on germination of cottonseed*

No.	Treatment.	Temperature.	Germination.		Relative.
			4 days.	8 days.	
		° C.	*Per cent.*	*Per cent.*	*Per cent.*
1	None	25	85	85	100
2	1 per cent of clover	25	55	55	64
3	None	30	95	95	100
4	1 per cent of clover	30	35	35	36
5	None	37	100	100	100
6	1 per cent of clover	37	80	80	80

About 30° C. seems to give the greatest injury; lower or higher temperatures fail to cause so great a decrease in germination.

EFFECT OF CERTAIN DECOMPOSITION PRODUCTS

In the decomposition of plant tissue many substances are liberated—e. g., ammonia and carbon dioxid. The relation of ammonium hydroxid to seed germination has been studied by Bokorny (3; 4, p. 37). He found that small quantities of ammonium hydroxid, 0.02 per cent, greatly retarded the germination of cress. It seems that the active protein of the cell is very sensitive to ammonia.

AMMONIUM HYDROXID

A series of tests was made using from 0.1 to 0.01 per cent of ammonium hydroxid. Four different seeds, cotton, corn, soybeans, and wheat, were allowed to germinate between cloths saturated with the varying concentrations of ammonium hydroxid. It was found that 0.05 or 0.01 per cent proved injurious, while 0.1 per cent prohibited all germination.

Since it was established that ammonia is harmful to seed germination, another test was carried out to study the ammonia produced by micro-organisms. The results of this study are shown in Table X.

TABLE X.—*Effect of sugar and of clover on ammonification*

Time in 2-day intervals.	Ammonia nitrogen in 100 gm. of soil.		
	No treatment.	1 per cent of sugar added.	1 per cent of clover added.
	Mgm.	*Mgm.*	*Mgm.*
1	1. 98	2. 0	3. 3
2	.....	2. 1	4. 3
3	.....	1. 96	2. 8
4	.....	1. 4	2. 4
5	.....	1. 4	2. 5
6	1. 90	2. 5	2. 6
Total	.....	11. 36	17. 9

Since ammonia formation is largely a product of bacterial action, it was thought that sugar or green manure would cause an enormous increase in this substance. The data of Table X show a slight gain in ammonia in the treated soils, but the amount is far too small to affect germination seriously

CARBON DIOXID

It was found that carbon dioxid, when added in large quantities, retards germination but does not cause the seeds to decay. As soon as the carbon dioxid is removed, germination proceeds in a normal manner. In Table XI is given the periodic evolution of carbon dioxid from soil treated with 1 per cent of sugar and 1 per cent of clover.

TABLE XI.—*Effect of sugar and clover on carbon-dioxid evolution*

Time in days.	Carbon dioxid in 100 gm. of soil.		
	No treatment.	1 per cent of sugar added.	1 per cent of clover added.
	Mgm.	*Mgm.*	*Mgm.*
1	4. 62	22. 0	16. 02
2	6. 82	17. 2	12. 7
3	9. 46	36. 52	22. 0
4	7. 21	37. 84	22. 75
5	7. 57	33. 97	22. 7
6	7. 74	29. 35	24. 2
7	7. 65	26. 40	24. 42
8	9. 68	25. 30	22. 22
Total	60. 75	228. 58	167. 01

From the data in this table it is evident that the amount of carbon dioxid evolved in the presence of sugar or clover is far too small to exert a marked effect on germinating seeds.

CALCIUM CARBONATE

It is well known that free acids greatly retard or prohibit germination (3; 4, p. 37). Aside from the direct effect on seeds, an acid reaction may favor the growth of injurious micro-organisms. Accordingly, two series of tests were made, using a neutral and an acid soil with varying amounts of limestone ($CaCO_3$). The results of the first test are given in Table XII.

TABLE XII.—*Effect of green clover and calcium carbonate on the germination of cottonseed*

No.	Treatment.	Germination.			
		1 week.	2 weeks.	3 weeks.	Relative.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	None	85	85	85	100
2	1 per cent of clover	55	55	55	64
3	1 per cent of clover, 0.1 per cent of calcium carbonate	35	.....	.....	40
4	1 per cent of clover, 0.2 per cent of calcium carbonate	15	.....	.....	17
5	1 per cent of clover, 0.5 per cent of calcium carbonate	15	.....	.....	17
6	1 per cent of clover, 1.0 per cent of calcium carbonate	10	.....	.....	11

The data show clearly that limestone in concentrations of from 0.1 to 1 per cent seriously injured the germination of cotton. The seedlings from limed soils died during the first or second week. A second test, similar to the above, was carried out, using acid soil. Here again calcium carbonate seemed to stimulate the injurious factor.

EFFECT OF HEAT

The results of previous tests indicate very strongly the biological nature of the factor injurious to germination. For example, reduced germination is largely associated with the first stages of decomposition. Second, the data seem to exclude the possibility of harmful gaseous products. It is conceivable that in the early stages of decomposition green tissue is favorable to the growth of certain organisms injurious to germination. Accordingly, a series of experiments were made in which the amount and form of green manure applied, the seed, and the biological factors were modified. From 1.5 to 3 per cent of green manure was added. To remove the biological factor, the jars and contents were sterilized in the autoclave at 15 pounds' pressure for two hours. The results of this study were recorded by photographs. Reading from left to right (Pl. LXXXIV, fig. 6), the jars were treated as follows: *A*, none,

unsterilized; *B*, 1.5 per cent of green manure, sterilized; *C*, 1.5 per cent of green manure, unsterilized; *D*, 3 per cent of green manure, sterilized; *E*, 3 per cent of green manure, unsterilized. The soil shown in the pots in Plate LXXXIII, figure 5, was treated with green oats, in Plate LXXXIV, figure 6, with green clover. Since the corn and wheat did not show any injury, these illustrations were not reproduced. The data from cotton, clover, and flax are presented in Plate LXXXIV, figures 1, 2, 3, 4, and 5. A glance at the seedlings in the sterilized soil shows conclusively that heat removes or renders inactive the harmful factor. The percentage germination of all crops in the sterilized green-manure soil was equal to that of the untreated controls. Apparently, sterilization has in some way prevented any injury from green-manuring. This is true with 1.5 or 3 per cent of green manure. When repeated, the same results were obtained. These data are given in Table XIII. All of the results point to an injurious agent of biological nature.

TABLE XIII.—*Effect of heat on the germination of cottonseed*

Letter.	Treatment.	Germination.			Relative.
		1 week.	2 weeks.	3 weeks.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
A	None	95	100	100	100
B	Sterilized	85	85	85	85
C	1 per cent of clover	10	10	10	10
D	1 per cent of clover sterilized.	80	80	80	80
E	1 per cent of oats	35	35	35	35
F	1 per cent of oats sterilized	85	90	90	90

SOURCE OF INJURIOUS AGENT

When portions of diseased seedlings are used to inoculate sterilized green-manured soil, the germination of oil seeds is greatly reduced. Numerous tests show that the harmful agent is readily transferred. From the data it must be concluded that the injury to seed germination is biological, probably due to bacteria or fungi. To study the nature of the agent, a series of tests was made with different micro-organisms.

EFFECT OF BACTERIA

In this series of tests bacteria from seed, from green manure, and from soil were studied. From the nature of the seed coat of cotton it is no doubt very rich in a number of bacteria. According to plate counts, the number of micro-organisms on cottonseed is over 122,000 per gram, or an average of nearly 11,000 organisms to one seed. A comparison of the germination of cottonseed free of bacteria and with bacteria, in unsterilized green-manured soil, did not disclose any difference in germination. The bacteria were removed (2) by exposing the seed to the action of hot mercuric chlorid ($HgCl_2$) or concentrated sulphuric acid (H_2SO_4). The use of sulphuric acid offers an easy and satisfactory method of

removing micro-organisms from cottonseed. The seeds were placed in a large glass-stoppered bottle containing concentrated sulphuric acid and glass beads. After shaking for two minutes, the seeds were removed with a platinum loop and washed in boiled water. From the data it seems that infection is from some source other than the seed.

It has been shown repeatedly that the addition of green manure to soil is followed by an enormous increase in the number of bacteria. Aside from the increase in bacterial food, the green manure carries with it a great number of bacteria (6, 8, 21). Tests with bacteria-free green manures failed to eliminate the injury.

About 16 pure cultures of bacteria were isolated from diseased seeds and green-manured soil. In order to test the effect of these various micro-organisms on germination, sterilized green-manured soil was inoculated with the various species of bacteria and seeded. The tests were carried out in triplicate, using bacteria-free seed of cotton, peanut, and soybeans. Here, again, bacteria failed to show any effect on the germination of oil seeds. In addition to the pure cultures used in the above experiment, a study was made with four laboratory stock cultures, *Bacillus fluorescens liquefaciens*, *B. subtilis*, *B. mesentericus vulgatus*, and *Streptothrix bucallis*. Heavy inoculations of these organisms did not injure the germination of cottonseed or soybeans. This agrees with the results of earlier workers (12, 13, 15, 18)—that is, bacteria grown on rich nitrogenous media do not injure seed germination. An exception to this is noted with cracked or injured seeds.

EFFECT OF FUNGI

From a study of tests carried out with various combinations of sterilized soil, green manure, and seeds free of micro-organisms, it was found that the harmful factor occurs chiefly in soil. The data in Table XIV show very conclusively the position of injury.

TABLE XIV.—*Effect of fungi on the germination of cottonseed*

No.	Treatment.	Germination.			
		1 week.	2 weeks.	3 weeks.	Relative.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	Sterilized soil, 1 per cent of sterilized clover.	20	70	70	100
2	Sterilized soil, 1 per cent of unsterilized clover.....	15	45	45	64
3	Unsterilized soil, 1 per cent of sterilized clover.....	.....	.....	.....	.....
4	Unsterilized soil, 1 per cent of unsterilized clover.....	.....	.....	.....	.....

It seems that the harmful agent is found both in soil and in plant tissue, although it is much more prevalent in soil. The results of later tests confirm this statement.

According to many investigators, fungi may injure seed germination (1, p. 30–39; 7, 12, 15). For example, Muth (15) found *Aspergillus niger* harmful to the germination of various seeds, while Atkinson (1, p. 30–39) and Bolley (5, p. 25–27) report a destruction of cotton and flax seedlings by species of Rhizoctonia and Fusarium.

Since it is established that certain soil fungi are injurious to very young seedlings, the question arises as to the occurrence and growth of parasitic fungi in green-manured soil. An experimental study of the occurrence of fungi in green-manured soil was made. Microscopical examinations of the diseased seeds showed the presence of many fungi on the primary root tip. Although no systematic study was made, some of the forms showed certain characteristics of the genus Rhizoctonia and others of the genus Fusarium. From portions of the diseased tissue plates were poured. In this way several species of fungi were isolated. These are described under laboratory numbers. All attempts to secure a pure culture of any species of Rhizoctonia failed. The various fungi were used to inoculate large tubes and jars of sterilized green-manured soil. The inoculated soil was planted to bacteria-free cotton-seed and soybeans. In the soil cultures no injury to germination was noted, except with culture 1. Here from 75 to 100 per cent of the seedlings were killed. Repeated tests with this unknown culture gave similar results. No injury to corn and wheat was noted from inoculations of culture 1, while soybeans and cotton were quickly destroyed.

Since the diseased root tips showed the presence of a Rhizoctonia-like fungus, it was arranged to study the effect of certain species of Rhizoctonia isolated from other sources. Two strains were employed—one isolated from potatoes, the other from alfalfa. The potato culture was secured from the Department of Plant Pathology of the Wisconsin Experiment Station; the alfalfa culture was supplied by Mr. Fred Jones, of the University of Wisconsin. Table XV gives the results of this test.

TABLE XV.—*Effect of Rhizoctonia spp. on the germination of cottonseed*

No.	Treatment and inoculum.	Germination.			Relative.
		1 week.	2 weeks.	3 weeks.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
1	None, sterilized. Uninoculated	75	80	80	100
2	1 per cent clover sterilized. Uninoculated	80	85	85	105
3	None, sterilized. Inoculated with *Rhizoctonia* sp. from alfalfa	60	70	70	86
4	1 per cent clover sterilized. Inoculated with *Rhizoctonia* sp. from alfalfa				
5	None, sterilized. Inoculated with *Rhizoctonia* sp. from potato	80	80	80	100
6	1 per cent clover sterilized. Inoculated with *Rhizoctonia* sp. from potato	85	85	85	105

Rhizoctonia sp. isolated from alfalfa proved fatal to cotton seedlings. Two weeks after inoculation all of the young plants were dead. On the contrary, a species of Rhizoctonia from potato produced no noticeable injury to cotton seedlings. This difference in the action of the two strains of Rhizoctonia is very evident from Plate LXXXIII, figure 6, and the data in Table XV. A species of Rhizoctonia from alfalfa produced nearly the same effect on soybeans as on cotton, while the germination of corn was not affected.

A study of the optimum conditions for the growth of culture 1 and *Rhizoctonia* sp. from alfalfa showed that about 25° to 30° C. is the most favorable temperature for both of these fungi. The results of a previous study indicate that about 25° C. is the optimum temperature for the growth of the harmful factor. From the data as a whole, it seems very conclusive that the fungus of culture 1 and probably other fungi are the causative agents in the destruction of germinating seeds.

DESCRIPTION OF THE INJURY

Examination of the diseased seeds shows that the injurious factor probably does not attack seeds until after germination. Apparently the fungus attacks the primary root soon after germination. This occurs when the primary root is from ½ to 1 cm. long. The hyphæ pierce the walls of the host, entirely envelop the root, and often penetrate deep within the tissue. In the affected region the tissue loses its form, turns brown in color, and soon rots. Under the microscope these diseased seedling roots are surrounded by a dense mantle of hyphæ, which are often brown-colored.

RELATION OF GREEN MANURE TO INJURY OF OIL SEEDS

Although the evidence at hand does not warrant a definite conclusion, the author suggests the following as a possible explanation for the injury: The green tissue furnishes an excellent medium for the development of fungi. This is especially true in the first stages of decomposition. After one or two weeks in the soil the green manure undergoes certain changes which render it unsuited to the growth of the injurious fungi.

Just why oily seeds should be so sensitive to fungi is not known. It is possible that the oil partly changes to fatty acids in the process of germination (9, 10). According to Schmidt (19, p. 300–303), oil and fatty acids favor the growth of certain fungi. The fungus may produce a fat-splitting enzym—for example, lipase. This offers a possible explanation for the selective action of the injurious fungi for oil seeds.

SUMMARY

(1) Green manures may seriously injure the germination of certain seeds.

(2) This injury is brought about by the action of certain parasitic fungi.

(3) In the first stages of decomposition of green clover, numerous fungi develop. Some of these fungi are very destructive to seedlings.

(4) Oil seeds as a class are very easily damaged by fungi. Starchy seeds, on the contrary, are very resistant.

(5) Cotton seed and soybeans are examples of seeds extremely sensitive to green manuring. The germination of flax, peanuts, hemp, mustard, and clover is reduced in the presence of decomposing plant tissue, but not to as great a degree as that of cottonseed or soybeans. The germination of buckwheat, corn, oats, and wheat is not affected by green manures.

(6) The damage to oil seeds from green manures is confined largely to the first stages of decomposition. Experimental evidence shows that two weeks after green manure is added it does not cause any serious injury to the germination of oil seeds.

(7) Small applications of calcium carbonate seemed to increase the injury to germination.

(8) The rate of germination determines to a certain extent the degree of injury. Slow germination is marked by a high percentage of diseased seedlings.

LITERATURE CITED

(1) ATKINSON, G. F.
1892. Some diseases of cotton. Ala. Agr. Exp. Sta. Bul. 41, 65 p., 25 fig., 1 pl.

(2) BARRE, H. W., and AULL, W. B.
1914. Hot water treatment for cotton anthracnose. *In* Science, n. s. v. 40, no. 1020, p. 109–110.

(3) BOKORNY, Thomas.
1912. Einwirkung einiger basischer Stoffe auf Keimpflanzen, Vergleich mit der Wirkung auf Mikroorganismen. *In* Centbl. Bakt. [etc.], Abt. 2, Bd. 32, No. 20/25, p. 587–605.

(4) ——
1913. Über den Einfluss verschiedener Substanzen auf die Keimung der Pflanzensamen. Wachstumsförderung durch einige. I. Mitteilung. *In* Biochem. Ztschr., Bd. 50, Heft 1/2, p. 1–48.

(5) BOLLEY, H. L.
1901. Flax wilt and flax sick soil. N. Dak. Agr. Exp. Sta. Bul. 50, 60 p., illus.

(6) BURRI, Robert.
1903. Die Bakterienvegetation auf der Oberfläche normal entwickelter Pflanzen. *In* Centbl. Bakt. [etc.], Abt. 2, Bd. 10, No. 24/25, p. 756–763.

(7) EDSON, H. A.
1915. Seedling diseases of sugar beets and their relation to root-rot and crown-rot. *In* Jour. Agr. Research, v. 4, no. 2, p. 135–168, pl. 16–26. Literature cited, p. 165–168.

(8) ESTEN, W. M., and MASON, C. J.
1908. Sources of bacteria in milk. Conn. Agr. Exp. Sta. Bul. 51, p. 65–109, fig. 16–23.

(9) GREEN, J. R.
1890. On the germination of the seed of the castor-oil plant (Ricinus communis). *In* Proc. Roy. Soc. London, v. 48, no. 294, p. 370–392.

(10) ——— and JACKSON, Henry.
1905. Further observations on the germination of the seed of the castor oil plant (Ricinus communis). *In* Proc. Roy. Soc. London, s. B, v. 77, no. 514, p. 69–85.

(11) HENRY, W. A.
1913. Feeds and Feeding . . . ed. 13, 613 p. Madison, Wis.

(12) HILTNER, Lorenz.
1902. Die Keimungsverhältnisse der Leguminosensamen und ihre Beeinflussung durch Organismenwirkung. *In* Arb. Biol. Abt. Land- u. Forstw. K. Gsndhtsamt., Bd. 3, Heft 1, p. 1–102, 4 fig.

(13) LAGERVALL, Algot.
1896. Effect of bacteria on germination. (Abstract.) *In* Exp. Sta. Rec., v. 8, no. 7, p. 566. [1897.] Original article appeared in Red. Verks. Ultuna Landtbrukinst., 1895, p. 49–52. 1896. Not seen.

(14) MIKULOWSKI-POMORSKI, J.
1913. The fertilizing value of the above-ground parts of cereals and leguminous plants. (Abstract.) *In* Exp. Sta. Rec., v. 31, no. 4, p. 320. 1914. Original article appeared *in* Kosmos [Lemberg], v. 38, p. 929–951. 1913. Not seen.

(15) MUTH.
1904. Untersuchungen über die Schwankungen bei Keimkraftprüfungen und ihre Ursachen. *In* Ber. Landw. Vers. Anst. Augustenb. 1903, p. 43–48.

(16) NOBBE, Friedrich.
1876. Handbuch der Samenkunde . . . 631 p., illus. Berlin.

(17) RUSSELL, H. L.
1913. Report of the director, 1911–1912. Wis. Agr. Exp. Sta. Bul. 228, 91 p., 37 fig.

(18) SAJÓ, Karl.
1901. Einige interessante Erscheinungen beim Keimen der Pflanzensamen. *In* Prometheus, Jahrg. 12, No. 587, p. 236–238.

(19) SCHMIDT, R. H.
1891. Ueber Aufnahme und Verarbeitung von fetten Oelen durch Pflanzen. *In* Flora, Jahrg. 74 (n. R. Jahrg. 49), Heft 3, p. 300–370.

(20) WEHMER, Carl.
1911. Die Pflanzenstoffe . . . 937 p. Jena.

(21) WIGGER, A.
1914. Untersuchung über die Bakterienflora einiger Kraftfuttermittel in frischem und gärendem Zustande, mit besonderer Berücksichtigung ihrer Einwirkung auf Milch. *In* Centbl. Bakt. [etc.], Abt. 2, Bd. 41, No. 1/8, p. 1–232. Literatur, p. 228–232.

PLATE LXXXIII

Cotton seedlings, showing the effect of green manures on their growth:

Fig. 1.—*A*, *B*, Control; *C*, *D*, 1 per cent of chopped green oats added to the soil; *E*, *F*, 1 per cent of chopped green clover added to the soil.

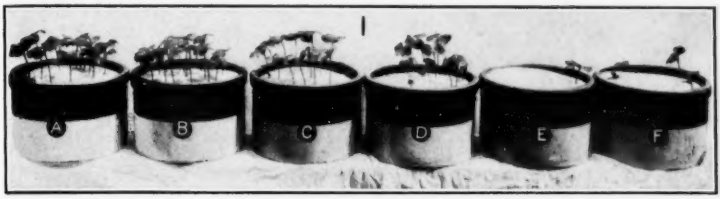
Fig. 2.—Effect of planting immediately after plowing under green manure: *A*, *B*, Control; *C*, *D*, 0.25 per cent of green manure added to the soil; *E*, *F*, 0.5 per cent of green manure added to the soil; *G*, *H*, 1 per cent of green manure added to the soil; *I*, *J*, 2 per cent of green manure added to the soil.

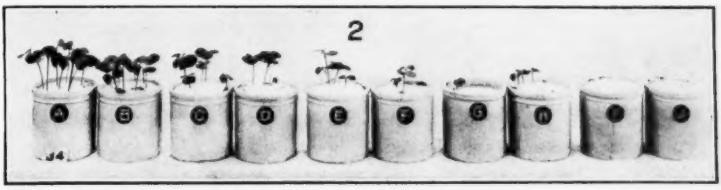
Fig. 3.—Effect of planting 2 weeks after plowing under green manure. *A*, *B*, Control; *C*, *D*, 0.25 per cent of green manure added to the soil; *E*, *F*, 0.5 per cent of green manure added to the soil; *G*, *H*, 1 per cent of green manure added to the soil; *I*, *J*, 2 per cent of green manure added to the soil.

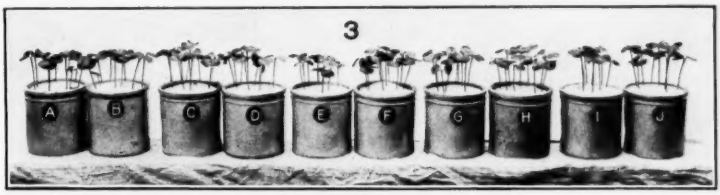
Fig. 4.—Effect of the depth of green manure on germination: *A*, Green manure placed in the bottom of the pot; *B*, green manure placed at the top of the pot; *C*, green manure placed in about the middle of the pot.

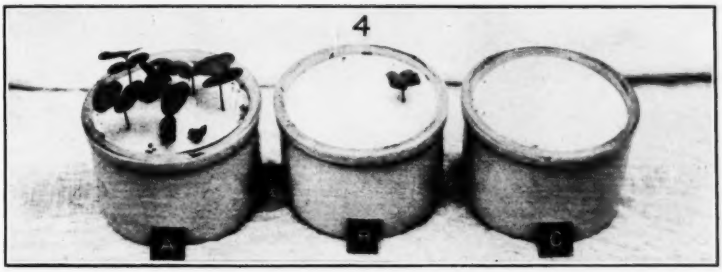
Fig. 5.—Effect of sterilized and unsterilized oats used as a green manure: *A*, Control; *B*, 1.5 per cent of oats added and the mixture sterilized; *C*, 1.5 per cent of oats added without sterilization; *D*, 3 per cent of oats added and the mixture sterilized; *E*, 3 per cent of oats added without sterilization.

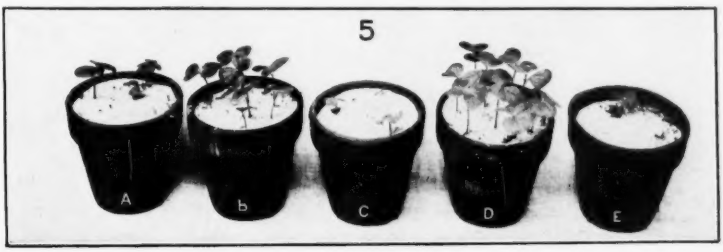
Fig. 6.—Effect of *Rhizoctonia* sp. on germination in the presence of green manure: *A*, *B*, Control; *C*, *D*, sterilized soil treated with green manure; *E*, *F*, sterilized soil inoculated with *Rhizoctonia* sp. from potatoes; *G*, *H*, sterilized soil treated with green manure and inoculated with *Rhizoctonia* sp. from alfalfa.


1
A
B
C
D
E
F

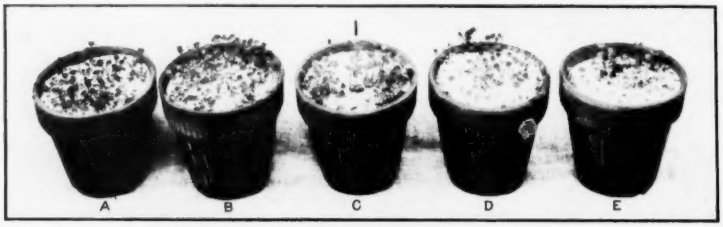

2

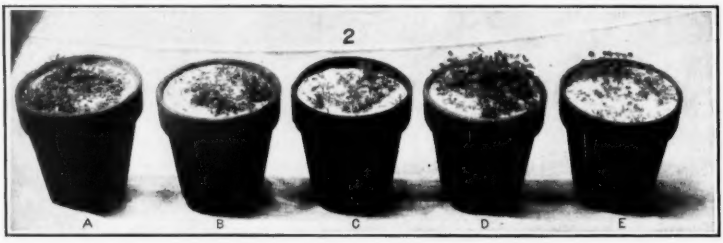

3
A
B
C
D
E
F
G
H
I
J


4
A
B
C

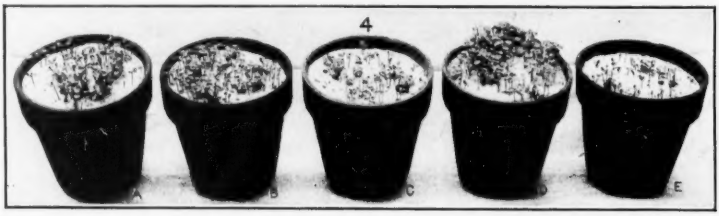

5
A
b
C
D
E

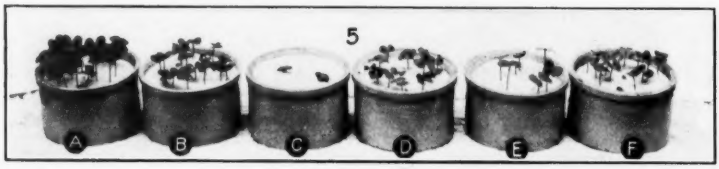
6
G
H


1
A
B
C
D
E


2
A
B
C
D
E

3
A
B
C
D
E


4


5
A
B
C
D
E
F

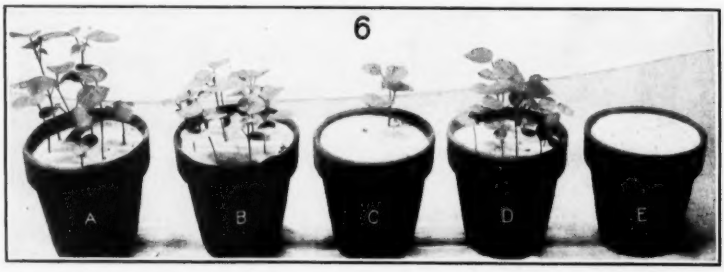

6
A
B
C
D
E

PLATE LXXXIV

Clover, flax, and cotton seedlings, showing the relation of green manures to germination in sterilized and unsterilized soil:

Fig. 1.—Clover: *A*, control; *B*, 1.5 per cent of chopped green oats added and the mixture sterilized; *C*, 1.5 per cent of chopped green oats added and the mixture not sterilized; *D*, 3 per cent of chopped oats added and the mixture sterilized; *E*, 3 per cent of chopped oats added and the mixture not sterilized.

Fig. 2.—Clover: *A*, control; *B*, 1.5 per cent of chopped clover added to the soil and the mixture sterilized; *C*, 1.5 per cent of chopped clover added to the soil and the mixture not sterilized; *D*, 3 per cent of chopped clover added to the soil and the mixture sterilized; *E*, 3 per cent of chopped clover added to the soil and the mixture not sterilized.

Fig. 3.—Flax: *A*, control; *B*, 1.5 per cent of chopped oats added to the soil and the mixture sterilized; *C*, 1.5 per cent of chopped oats added to the soil and the mixture not sterilized; *D*, 3 per cent of chopped oats added to the soil and the mixture sterilized; *E*, 3 per cent of chopped oats added and the mixture not sterilized.

Fig. 4.—Flax: *A*, control; *B*, 1.5 per cent of chopped clover added and the mixture sterilized; *C*, 1.5 per cent of chopped clover added to the soil and the mixture not sterilized; *D*, 3 per cent of chopped clover added to the soil and the mixture sterilized; *E*, 3 per cent of chopped clover added to the soil and the mixture not sterilized.

Fig. 5.—Cotton: *A*, control; B, soil sterilized; *C*, 1 per cent of chopped clover added to the soil and the mixture not sterilized; *D*, 1 per cent of chopped oats added to the soil and the mixture not sterilized; *E*, 1 per cent of chopped clover added to the soil and the mixture sterilized; *F*, 1 per cent of chopped oats added to the soil and the mixture sterilized.

Fig. 6.—Cotton: *A*, control; *B*, 1.5 per cent of chopped clover added to the soil and the mixture sterilized; *C*, 1.5 per cent of chopped clover added to the soil and the mixture not sterilized; *D*, 3 per cent of chopped clover added to the soil and the mixture sterilized; *E*, 3 per cent of chopped clover added to the soil and the mixture not sterilized.

A NEW SPRAY NOZZLE

By C. W. Woodworth,
Entomologist, Agricultural Experiment Station of the University of California

INTRODUCTION

A new principle has been discovered in nozzle construction whereby a flat spray can be produced with a uniform distribution of the water comparable to that of the hollow cone of spray from a cyclone nozzle. Hitherto all flat sprays have been of lenticular section, breaking up into fine mist on the sides and into relatively coarse drops in the center. It was observed that the flat spray produced by two impinging streams was at right angles to the original plane of motion of the two streams, but when the streams failed to meet squarely the plane was shifted and could, in fact, be moved through an arc of 180° with a very great change in the distribution of the water currents. It requires only a slight angular deviation to decrease very perceptibly the coarseness of the central drops, producing greater uniformity, and a position can be reached in which the coarsest drops are on the edge, those in the center therefore being the finest.

The principle finally discovered was that when two streams meet across half their section the resulting sheet of spray will be of practically uniform thickness throughout, occupying a plane 45° from the plane of the streams and finally breaking up into drops of great fineness and uniformity.

PRODUCTION OF SPRAY

There are two causes that may act in the production of spray particles: (1) Friction, which may cause an eddy along the edge of the stream sufficient to break the surface tension and allow the small eddying masses to fly off from the column of water; and (2) divergence of the direction of motion of the particles, resulting in the thinning out of the water mass in the form of irregular sheets until the surface film finally gives way and the sheet of water is suddenly converted into drops.

Both methods may be seen in the breaking up of the stream from a simple nozzle where, from the sides of the solid column of water, very minute particles of mist are given off, while the velocity and friction are great. With decreasing velocity farther on the eddies become larger, the mist gradually becomes coarser, and, finally, as the spread of the stream makes it break up into irregular sheets of water, the size of the drops produced by the second process results in an intermingling of drops of all sizes. At first the drops are very accurately graduated,

Journal of Agricultural Research,
Dept. of Agriculture, Washington, D. C.
cp

Vol. V, No. 25
Mar. 20, 1916
Cal.—4

those of the same size being produced at the same distance from the nozzle, but when the second process replaces friction as a cause of spray production, irregularity results, owing to the irregular shapes of the water sheets.

In a cyclone nozzle the stream at once diverges widely in the form of a hollow cone. Friction plays no part in the production of the spray, but the cone increases so rapidly in diameter that the liquid soon becomes a very thin sheet of unvarying thinness all the way around, and breaks into a uniformly fine mist. The uniformity may be assumed from the fact that on all sides the sheet extends an equal distance from the orifice before breaking into a spray, and experimentally can be shown to exhibit to an equally high degree both fineness and uniformity.

Figure 1 expresses in a diagrammatic form the facts shown by the photographs. The circles show the actual positions of the orifices in

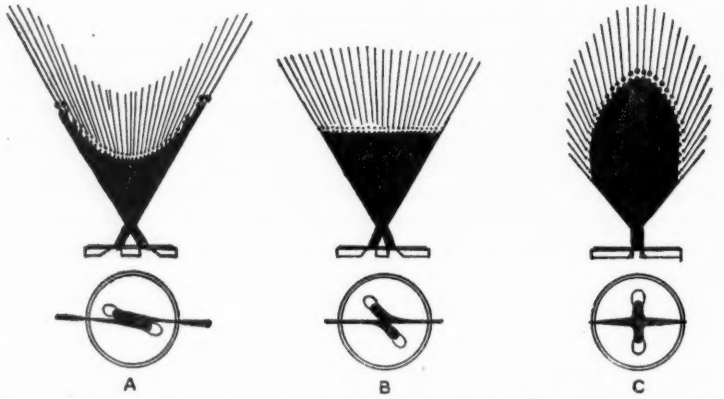


FIG. 1.—Diagram showing the characteristic differences between the three forms of impinging-stream nozzles.

each case and the black transverse marks give the effect of the impinging streams; the water remains thickest in the middle in *C*, thickest at the edges in *A*, while in *B* it is spread out evenly.

Above, the black portion indicates the water sheet, the sizes of the spots along the margin indicate the sizes of drops produced at these points, and the approximate velocity of the drops is shown by the length of the lines radiating from these spots.

SPRAYS PRODUCED BY IMPINGING STREAMS

The actual movement of the water in forming a spray through the impact of two streams is shown in Plate LXXXV and Plate LXXXVI, figure 1. It was not found practicable to secure the successive pictures with sufficient rapidity to show more than two steps in the forming spray, but by interpolating, a fairly satisfactory series was obtained. The

right-hand nozzle is of the common type where the streams impinge squarely. The middle nozzle is of the new type, but not strictly comparable with the former, since the streams come together at a broader angle, making a wider spray. Indeed, when the spray is under full pressure (Pl. LXXXVI, fig. 1) the spread is too wide, producing a lateral dribble and marginal fringe of spray. The left-hand spray is intermediate in angle and spread and gives the fish-tail effect.

The contrast is shown from the first illustration, the fish tail having thick marginal zones and the other two thick central zones, much shorter in the middle nozzle. In Plate LXXXVI, figure 1, where the spray sheets assume their normal proportions under high pressure, the large size of the white patch in the middle corresponds to the better final distribution of the spray particles. The irregularity of the spot shown on the left of this white patch is due to an irregularity in the orifice on the opposite side.

In Plate LXXXVI, figure 2, which shows the result of a sudden decrease of pressure, the character of the water sheets becomes especially evident, since they are increased greatly in size and the production of spray almost ceases.

ADVANTAGE OF A FLAT SPRAY

The cyclone nozzle leaves nothing to be desired in the way of fineness and uniformity of spray, but it has the disadvantage of making a ring of spray which surrounds instead of touching the object towards which the nozzle is directed. It is very difficult for one handling the nozzle to keep in mind the fact that the spray is strictly limited to the visible parts of the cone. A flat spray, on the other hand, reaches the point aimed at and is more available for treating branches of trees, for example, where the desire is to concentrate the spray on a line. For general spraying also the use of a flat spray, like the use of a flat brush for painting, gives uniform results more quickly and easily. For these reasons, while no other nozzle on the market produces a flat spray comparable in quality to the spray produced by the various types of cyclone nozzles, they are, nevertheless, more extensively used than the cyclone nozzles.

ADVANTAGE OF UNIFORMITY AND FINENESS

The use of nozzles of the flat type is generally acknowledged to be for the purpose of securing the flat shape of spray fan and is not a rejection of the principle that a uniformly fine spray is the most desirable. In fact, the use of these nozzles is generally associated with the use of high pressures, whereby the defects of a poor grade of nozzle are less apparent. The particular advantage of fineness is that it makes possible the even distribution of the spray material.

Fineness involves evenness. In a nozzle giving coarse drops, part of the material is in a finely divided state, and the improvement in a spray

nozzle comes through decreasing the size of all but the smallest particles and thus increasing the proportion of minute particles until, as in the cyclone nozzle, practically all of the material is in the most finely divided state and is therefore also uniform. This improvement can be produced by increasing the pressure or decreasing the size of the stream. Under the same pressure a nozzle with a large orifice gives coarser drops than a similar nozzle with a small orifice. Therefore, where a larger volume of spray is desired, it has been the practice to duplicate the nozzles rather than enlarge them, giving clusters of nozzles; but where high pressure is available, large nozzles, particularly those of the better type, may be used. With extreme pressures, such as were employed in the gipsy-moth work and in the walnut spraying in California, a nozzle of the poorest quality and rather large size has proved to be practical. In nearly all cases the desirability of fine and uniform sprays, in order to secure evenness of distribution, has been recognized. It is possible, however, that under some circumstances a driving spray may be desirable, and this can be secured only by the use of less efficient nozzles.

VARIATION IN FINENESS

The sizes of the smallest drops in a spray are not necessarily the same, particularly when made by the breaking up of a sheet of water. By a change in the proportions of the eddy chamber in a cyclone nozzle or by a change in spraying pressure the diameter of the cone at the point of breaking can be changed, and the drops will remain uniform, but will be of a different size than before. In the new type of nozzle here described the angle of impact and the spraying pressure exert similar effects, and a series of nozzles can be produced covering much the same range obtainable in a cyclone nozzle and distinguishable by the width and length of the fan.

Only relatively small drops in the spray in either case are obtained, and these show great uniformity, the variation in size being inside of rather narrow limits.

The new type of nozzle is the form in which the spray is in a plane inclined at the angle of 45° from the plane of the impinging streams, but between that and the usual style, having the spray in a plane 90° from that of the streams, there is the possibility of any number of intermediate forms that present any desired degree of uniformity in the size of the drops. Should a compromise nozzle giving a driving spray with greater uniformity than in the existing nozzles be desired, it can readily be constructed. The same could be secured by a disproportion between the sizes of the two streams, and in this case the coarser portion would be at one edge instead of at the center of the fan. This form might be desirable for some spot-spraying for scale insects, and it might be desirable to have a means of controlling the size of one of the streams.

WHERE THE NEW NOZZLES ARE IMPRACTICAL

Because the spray must first be separated into two streams in this type of nozzle it becomes particularly liable to clogging and should not be used for any spraying where there is any such tendency—e. g., with Bordeaux mixture.

Most of the spray materials now used, however, are clear solutions and give no trouble in the nozzle.

LONG- AND SHORT-DISTANCE NOZZLES

When the angle is widest between the impinging streams, the angle of the fan is likewise widest, the drops finest, and the carrying distance of the spray the shortest.

An acute angle between the impinging streams produces a very narrow spray which carries a longer distance, but may perhaps finally reach nearly as great a width as that of the rapidly spreading short-distance spray.

Some prefer a long-distance nozzle and use it close to an object, as where spot spraying on a tree trunk is desired. The new type of nozzle lends itself very readily to adjustment to any degree of distance, from the shortest to nearly the longest found in spray nozzles.

ADJUSTMENT

Any form of two-stream nozzle, like that known as the calla, or lily, nozzles, can be quickly converted into a nozzle of the new type by the use of a reamer, slightly enlarging the two apertures on opposite sides by working the instrument obliquely to the surface of the nozzle and trying it from time to time until the spray sheet stands at 45°.

The same process will enable one to adjust a nozzle at any time should it wear irregularly enough to change the angle of the spray fan. The shape of the fan is a good index of the correct adjustment. If the angle is just right, the fan is triangular; if less than 45°, it is shortest in the center and the spray is coarser at the ends. If the angle is more than 45°, the fan is longest in the center and the spray coarsest at this point.

With care the reamer can be so used as to effect the change in the stream without enlarging the hole at the surface, and, therefore, not changing the volume of discharge. It may be possible to change the angle of the spread of the fan by reaming out beneath on the side adjacent to or opposite the other hole. One should continually try a nozzle while adjusting it, so as not to carry the work too far.

SUMMARY

(1) A new principle employed in nozzle construction will produce a flat spray with the qualities of a cyclone nozzle.

(2) A uniform sheet of water breaking along its edge produces drops of uniform size.

(3) A flat spray is more easily directed and produces a more uniform distribution than the cone of spray from a cyclone nozzle.

(4) Uniformly fine drops of spray aid in securing uniformity of distribution.

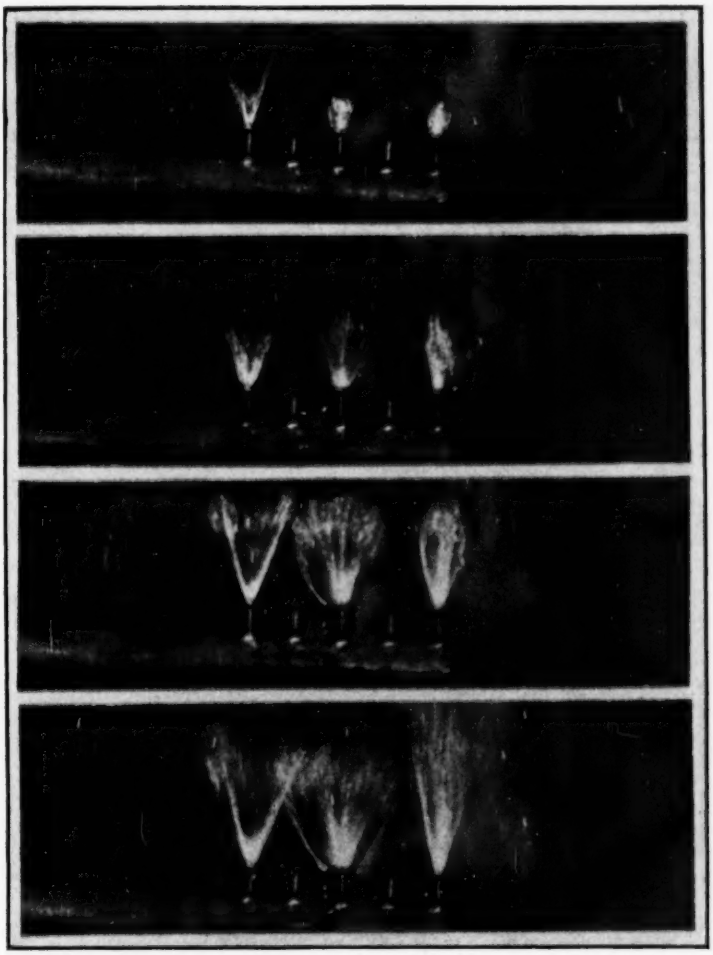
(5) The new nozzle allows some variation in size of spray.

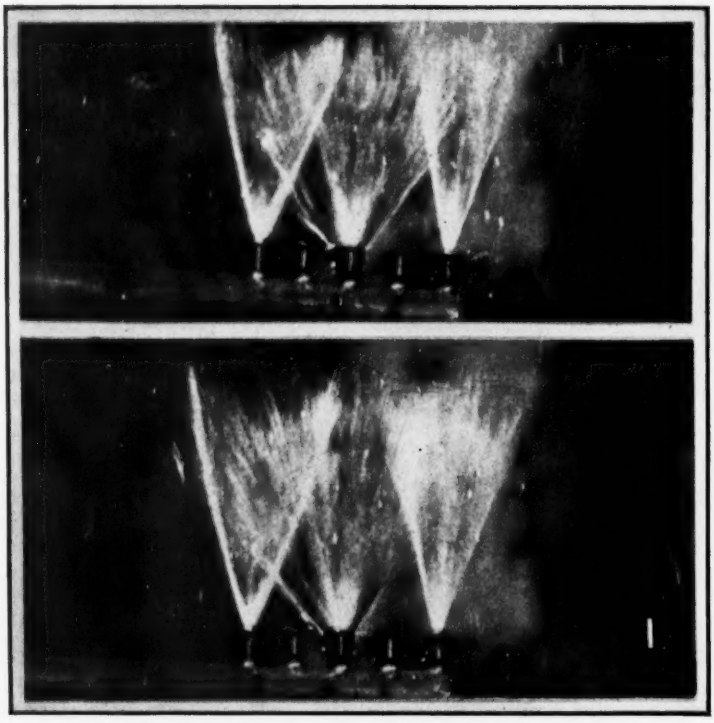
(6) It also may be made into a long- or short-distance nozzle.

(7) It can be easily constructed by modifying existing nozzles and may be adjusted if it becomes worn.

PLATE LXXXV

The beginning of the spray from three kinds of nozzles, as photographed with a moving-picture camera.




1

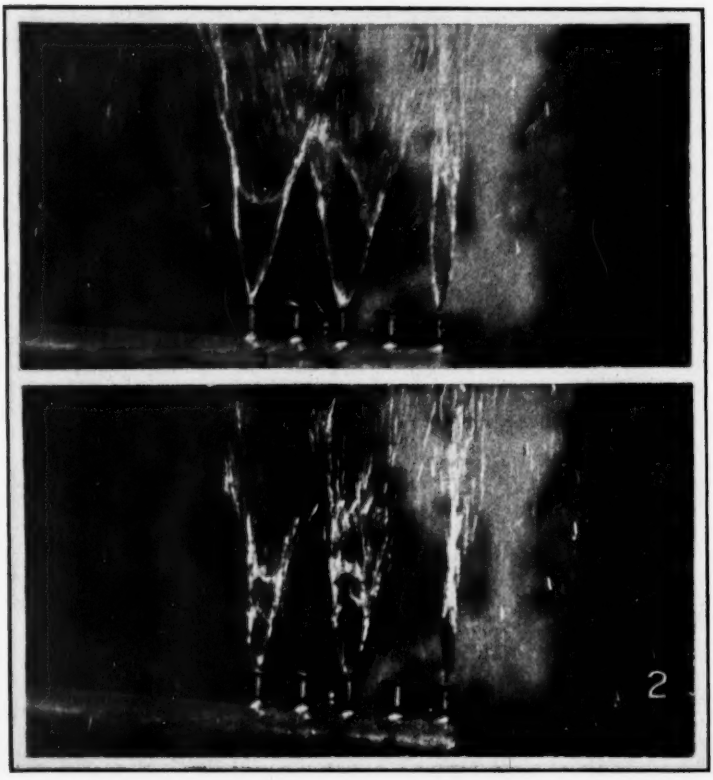

2

PLATE LXXXVI

Fig. 1.—The appearance of spray from three kinds of nozzles as full pressure is applied (a continuation of Plate LXXXV).

Fig. 2.—Two stages at the end of the spray as the pressure is reduced.

A NEW INTERPRETATION OF THE RELATIONSHIPS OF TEMPERATURE AND HUMIDITY TO INSECT DEVELOPMENT

By W. DWIGHT PIERCE,

Entomological Assistant, Southern Field Crop Insect Investigations, Bureau of Entomology

INTRODUCTION

Upon the proper interpretation of the laws of climatic control of life rests the solution of many practical problems, and inasmuch as all plant and animal life reacts to climate in the same general manner it is apparent that the study of the climatic control of insect development may throw light upon the problems of all other forms of life. It has been apparent to some workers in the field of ecology that our so-called laws of effective temperature were deficient in many respects. A large number of phenomena were not properly explained by any known theory. It is with the hope that the present interpretation may come closer to the truth that this paper has been prepared.

Biologists for years were laboring with the theory of a fixed zero of effective temperature for all life, and only recently was it accepted that each species might have a different zero. It has been the custom to determine the thermal constant for any given activity by multiplying the number of effective degrees accumulated above the effective zero in daily units of mean temperature by the time in which the given phenomenon took place. The noneffective low temperatures were eliminated, but not the time in which they were experienced. Inasmuch as most workers were located in north-temperate climates, where high noneffective temperatures seldom occur, it had not occurred to them that some high temperatures might not be effective and that there was another boundary to the effective zone besides the zero. These high temperatures and the time in which they are experienced must be eliminated. In addition to all of these errors in method, there has been no correlation of the humidity factor until very recently, although now many workers are trying to solve the part played by this factor.

The principal data upon which the writer has based his studies include records of thousands of individual boll weevils (*Anthonomus grandis* Boh. and *A. g. thurberiae* Pierce), made by the members of the boll-weevil force under the direction of Mr. W. D. Hunter and the writer at various localities in Texas, Louisiana, and Arizona throughout the period of years from 1902 to 1915. At each place where biological notes were made a thermograph-hygrograph record was kept, and this record was

Journal of Agricultural Research,
Dept. of Agriculture, Washington, D. C.
dc

Vol. V, No. 25
Mar. 20, 1916
K—27

checked twice daily by maximum and minimum thermometer and sling-psychrometer readings. The means of temperature and humidity are based upon these records. In addition to the natural records, a series of artificial-cold experiments were conducted at various times, and the writer recently conducted an extensive series of artificial-heat experiments with definite humidity control in order to determine the effects of heat.

EXPERIMENTAL METHODS

Before venturing to present this new interpretation the writer has thoroughly discussed it with many prominent workers, and it is now proposed for more extensive criticism and elaboration.

To express the relationship of the two factors, temperature and humidity, to insect metabolism, development, and activity, a temperature scale may be marked off on the vertical line of a sheet of plotting paper and a humidity scale from left to right on the horizontal line. There are, for any given insect, definite boundaries of atmospheric temperature and humidity within which the life of the species revolves. There is a temperature below which, even for the shortest time, life is impossible—the absolute minimum fatal temperature. There is also a temperature above which, even for a moment, life is impossible—the absolute maximum fatal temperature. Absolute dryness is more or less prohibitive of life and so is absolute humidity, or saturation, although some insects may be adapted better to withstand extremes of humidity than others. It is quite possible that the boundaries of humidity may be 0 and 100 per cent, or infinitesimally close thereto.

The diagrammatic figure sought, however, has four definite absolute boundaries—the maximum and minimum temperatures and humidities.

Within the limits which we have thus defined there exist conditions under which all the activities of the species reach their maximum efficiency. It has been conceived by most writers that this maximum efficiency was reached at a definite point known as the optimum. It seems more likely that it will prove to be a zone of humidities and temperatures of more or less restricted area. A careful study of the records of any species, charting for the time required for each activity and the temperature and then similarly for humidity, will disclose temperature and humidity points of maximum efficiency. With the boll weevil these points lie approximately near 83° F. and 65 per cent of relative humidity.

ZONES OF CLIMATIC RELATIONS

At any ordinary humidity, starting with the absolute minimum fatal temperature, as the temperature increases a longer and longer time of exposure is required to kill, until a point is reached at which life continues indefinitely. This zone of temperatures has been called the zone of fatal temperatures.

As the temperature continues to rise it passes through a zone of ineffective temperatures, known commonly as the zone of hibernation, which the writer will shortly prove to be an inappropriate term. At the lowest temperatures in this zone complete dormancy without metabolism is found; but as the temperature increases a gradual approach to sensibility is noted, first metabolism, next movement, and then the necessity of feeding. The point at which metabolism or growth begins at a given humidity is the zero of effective temperature.

As the temperature increases above this zero the activity is at first very sluggish, but becomes more and more active until the so-called optimum is reached, and from this point upward the temperatures cause less and less activity, inducing stupor and finally sleep or coma.

At the point of coma begins the zone of ineffective temperatures formerly known as estivation. With the increase of temperature sleep becomes more and more sound until a point is reached at which death occurs after long exposure. At this point begins the zone of high fatal temperatures at which death occurs at shorter and shorter periods until it is instantaneous at the absolute maximum fatal temperature. This completes the vertical cross section of the figure desired. A statement regarding these vertical zones was first published by the Bureau of Entomology in 1912.[1]

In the past, however, the fact that a similar horizontal cross section at any temperature can be made, starting at absolute dryness and reading toward absolute humidity, has not been recognized. In this manner are shown zones of fatal dryness, dryness causing stupor, increasingly effective humidity, the most effective humidity, decreasingly effective humidity, excessive humidity causing drowsiness, and finally fatal humidity, at least under certain conditions of exposure.

In the case of the boll weevil the resulting figure is a series of concentric ellipses centered about the optimum and with diagonal axes. On the accompanying diagram the main details of the relations of temperature and humidity to the boll weevil are brought out. Only a few of the more salient records are included. The development in buds (cotton squares) is based upon hundreds of individual records, but is not reported in detail. The outer lines are much less definitely located than the inner ones, but whatever their actual location the picture would be substantially the same.

EFFECTIVE TEMPERATURE

Workers who have used the zero of effective temperature in their studies will note that, according to the present theory, the zero when charted is an elliptical curve representing a different point at each degree

[1] Hunter, W. D., and Pierce, W. D. Mexican cotton-boll weevil. 62d Cong., 2d Sess., Sen. Doc. 305 (U. S. Dept. Agr. Bur. Ent. Bul. 114), p. 125–128. 1912.

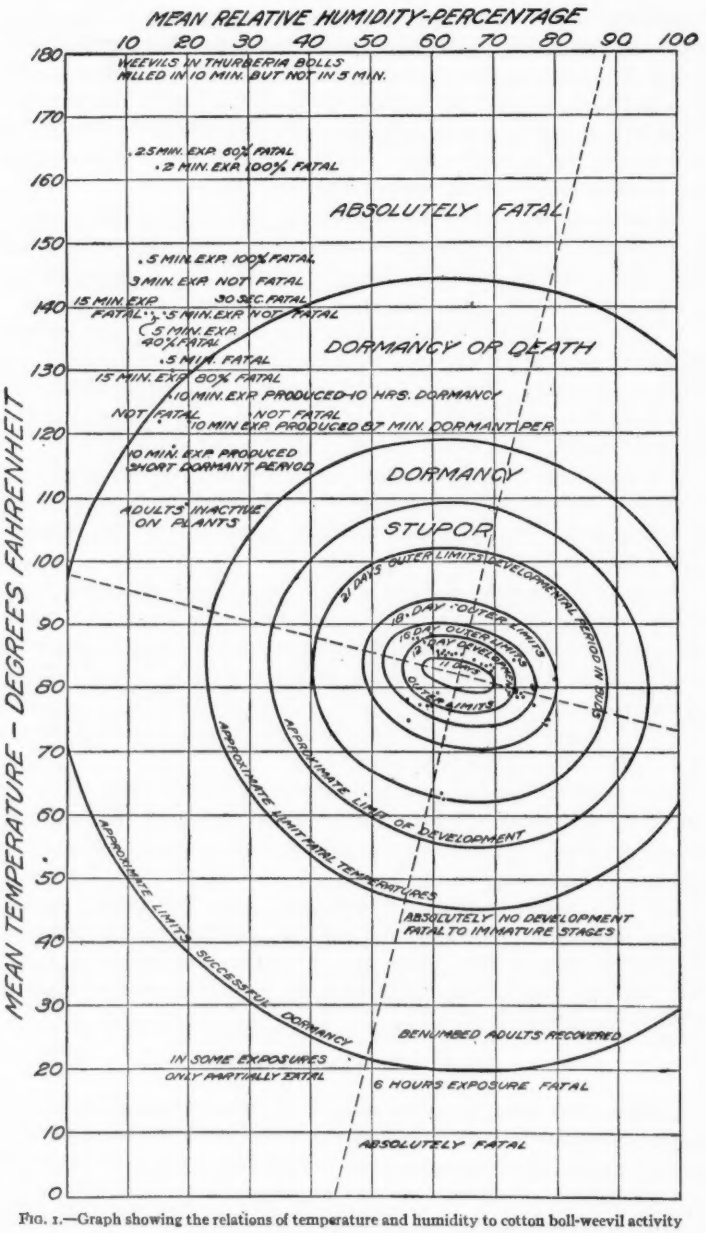

MEAN RELATIVE HUMIDITY-PERCENTAGE
10 20 30 40 50 60 70 80 90 100
MEAN TEMPERATURE - DEGREES FAHRENHEIT
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
WEEVILS IN THURBERIA BOLLS KILLED IN 10 MIN. BUT NOT IN 5 MIN.
.25 MIN. EXP. 60% FATAL
.2 MIN. EXP. 100% FATAL
ABSOLUTELY FATAL
.5 MIN. EXP. 100% FATAL
3 MIN. EXP. NOT FATAL
15 MIN. EXP. FATAL
30 SEC. FATAL
5 MIN. EXP. NOT FATAL
5 MIN. EXP. 40% FATAL
.5 MIN. FATAL
DORMANCY OR DEATH
15 MIN. EXP. 80% FATAL
10 MIN. EXP. PRODUCED 10 HRS. DORMANCY
NOT FATAL
NOT FATAL
10 MIN. EXP. PRODUCED 87 MIN. DORMANT PER.
10 MIN. EXP. PRODUCED SHORT DORMANT PERIOD
DORMANCY
ADULTS INACTIVE ON PLANTS
STUPOR
21 DAYS OUTER LIMITS DEVELOPMENTAL PERIOD IN STATE
18 DAY OUTER LIMITS
16 DAY OUTER LIMITS
14 DAY OUTER LIMITS
11 DAYS
OUTER LIMITS
APPROXIMATE LIMIT OF DEVELOPMENT
APPROXIMATE LIMIT FATAL TEMPERATURES
ABSOLUTELY NO DEVELOPMENT FATAL TO IMMATURE STAGES
APPROXIMATE LIMITS SUCCESSFUL DORMANCY
BENUMBED ADULTS RECOVERED
IN SOME EXPOSURES ONLY PARTIALLY FATAL
6 HOURS EXPOSURE FATAL
ABSOLUTELY FATAL

FIG. 1.—Graph showing the relations of temperature and humidity to cotton boll-weevil activity

of humidity. Because of the difficulty of computing this zero, the writer has been requested to describe his method of computing effective temperatures.

The first step is to tabulate all records of a given mean percentage of humidity on a single sheet. The zone of effective temperatures must be worked out separately at each degree of humidity. Only by a laborious series of testings can the first zero be approximated, unless the worker finds it by a fortunate chance. The total effective temperature is the criterion by which we finally know when we have rightly defined the limits of the zero. This is known as the thermal constant and is the multiple of the mean of the effective temperatures (between the zero and the absolute), figured in day units, by the time in which these effective temperatures were experienced. Noneffective temperatures, whether high or low, and the time in which they were experienced must be eliminated. The zone of effective temperatures will be finally reached for any given humidity when the

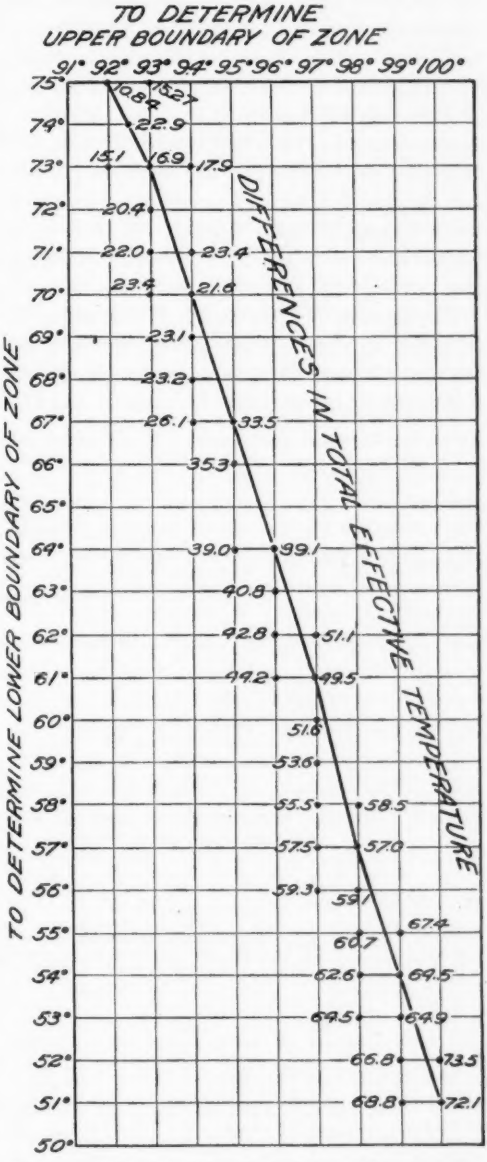


FIG. 2.—Graph showing the method of determining the zone of effective temperatures at a humidity of 56 per cent.

difference in the total effective temperatures is reduced to a minimum. At the start some arbitrary zero must be chosen and the effective temperatures computed above this. Then it is necessary to remove degree by degree at the top or bottom and note each time whether the difference in the total effective temperatures becomes larger or smaller. This process may be charted so that the general tendency can be seen. The figures found in the writer's attempt to establish the zone of effective temperatures for the boll weevil at 56 per cent humidity will illustrate the manner in which the points desired were ascertained. These results are presented in figure 2, and it will be seen that the first tentative zone chosen was 51° to 100° F. By much testing it was narrowed to within the limits of 75° to 92° F., for which the optimum is practically 83.5°.

Having obtained the limits of the zone, the records of development in cotton squares at a mean humidity of 55.9 per cent to 56.9 per cent, made at Victoria, Tex., in 1913, by Mr. B. R. Coad, of the Bureau of Entomology, are as shown in Tables I and II.

TABLE I.—*Records of development of Anthonomus grandis at Victoria, Tex., in 1913, at a humidity of 55.9 to 56.9 per cent*

Experiment.	Mean humidity.	Date of oviposition.	Time of maturing.	Actual period of development.	Number of weevils observed.		Total weevil days.	Actual temperature.		
					Male.	Female.		Absolute maximum.	Absolute minimum.	Mean.
	Per cent.			*Days.*				° *F.*	° *F.*	° *F.*
1.....	56.1	July 27	Aug. 9	13	6	2	104	104	73.2	88.2
2.....	56.4	July 26	Aug. 8	13	1	3	52	104	73.2	88.2
3.....	56.6	July 27	Aug. 10	14	.....	1	14	104	73.2	88.2
4.....	56.9	July 27	Aug. 11	15	.....	1	15	104	73.2	88.2
5.....	55.9	May 22	June 7	16	1	.....	16	95.5	54.5	78.2
Mean....	56.2	.....	.....	.....	Total. 8	7	201	.....	.....	.....

TABLE II.—*Records of development of Anthonomus grandis at Victoria, Tex., in 1913, in the zone of effective temperatures, 75° to 92° F.*

1[a] Experiment.	2[a] Number of weevils.	3[a] Mean humidity.	4[a] Humid time units.	5[a] Period experiencing effective temperature.	6[a] Total effective weevil days.	7[a] Mean effective temperature.	8[a] Effective thermal units.	9[a] Mean daily effective temperature. units.	10[a] Total effective temperature.	11[a] Humidity plus effective temperature.
		Per ct.		*Days.*		° *F.*			° *F.*	° *F.*
1.....	8	56.1	448.8	8.19	65.52	83.8	670.4	8.8	72.0	139.9
2.....	4	56.4	225.6	8.18	32.72	83.8	335.2	8.8	71.98	140.2
3.....	1	56.6	56.6	8.86	8.86	83.6	83.6	8.6	76.1	140.2
4.....	1	56.9	56.9	9.52	9.52	83.7	83.7	8.7	82.82	140.6
5.....	1	55.9	55.9	9.95	9.95	82.6	82.6	7.6	75.6	138.5
Total....	15	.....	843.8	.....	126.57	.....	1,255.5	.....	.....	.....
Average.	.....	56.2	.....	8.43	.....	83.7	.....	8.7	73.3	139.9
Difference...	.....	.....	.....	.....	.....	.....	.....	1.2	10.84	2.1

[a] Column 4 is product of columns 2 and 3. Column 5 is computed from the actual records. Column 6 is the product of 2 and 5. Column 8 is the product of 2 and 7. Column 9 is 7 minus the zero (75° F.). Column 10 is the product of columns 5 and 9. Column 11 is the sum of columns 3 and 7.

From these tables it will be seen that the effective period of development is from 8 to 10 days, averaging 8.43 days, while the actual development ranged from 13 to 16 days. It is noticeable that in all of the records the maximum as well as the minimum temperatures ran outside of the zone of effective temperatures. The total effective temperature ranged from 72° to 83° F., with 73.3° as the weighted mean and with a total difference of only 10.84°, a very small difference.

It is not necessary in this paper to give the further details of the zone of effective temperatures at other humidities. The determination of the zone for the next percentage of humidity is much less difficult, because it must be just a little narrower or a little wider than already determined. As the axis is diagonal, the upper and lower bounds will depart at a different rate. After several points have been determined, the axis can be located and then the figuring becomes very simple. It must be noted that every hour of effective temperature has its cumulative effect, even in the winter time.

ZONE OF INACTIVITY

One of the results of the acceptance of the present interpretation will be the necessity of discarding the conception of separate zones of hibernation and estivation. Physiologists have demonstrated that the effects of heat and cold on metabolism are alike. The writer has frequently noticed in field work the impossibility of differentiating between a frozen and a heat-killed boll-weevil larva. Prof. G. G. Becker, of Arkansas Agricultural College, several years ago observed that the fall army worm, *Laphygma frugiperda* S. and A., had two periods of activity and two of inactivity every day in the hot days in the Ozarks. Activity began in the morning and continued until the early part of the afternoon, when the heat caused the worms to be inactive for several hours. They then again became active during the early hours of the night, but the nights were cold and the worms became inactive until morning. The phenomena of a year were reproduced day by day. Inactivity due to cold in the summer time can not properly be called hibernation.

In Arizona the boll weevil is now native on wild cotton (*Thurberia thespesioides*). It normally breeds in the bolls in the fall, becoming adult by December 1, but remains in its cell throughout the cold winter and the warming spring. In some canyons there is a spring rainy season and *T. thespesioides* has a spring fruiting season. In these localities the moisture also releases the weevils from their cells and they begin breeding. A dry season follows and the weevils go to sleep. In other canyons the spring is not wet and the plants and weevils are inactive until the regular rainy season in August, when the long rest is broken. In some canyons the weevils therefore have two resting periods during the year, and in other canyons they are at rest from fall until summer. It not infrequently happens that the August rainy season does not materialize, and under

such circumstances the weevils stay in their cells and the plants remain dormant until the next year or perhaps for several years. As evidence of this the writer kept several of these weevils over 500 days without food or water, and one lived 626 days, dying only when moisture invaded the room where it was kept.

Hunter, Pratt, and Mitchell[1] record the unusual ability of larvæ of *Hermetia chrysopila* Loew, a cactus scavenger fly, to withstand long periods of drought. Larvæ in various stages of development were kept for more than 15 months without food and developed readily later when food was supplied. The very leathery integument seems to protect the insect against desiccation, and in other ways the larva has evidently adapted itself to long periods of waiting for favorable food, which, in the arid regions, depends upon the infrequent rains. Both of these instances are more properly resting periods due to dryness than to cold or heat.

NOMENCLATURE OF CLIMATIC EFFECTS ON LIFE

As charted, there are three elliptical zones which express the three principal effects of climate on life, viz, activity, inactivity, and death. The zone of activity may be known as the "thermopractic" zone (*Θερμός*, meaning heat, plus *πρακτικός*, meaning effective). The zone of inactivity may be known as the zone of "anesthesia" (*ἀναισθησία*, meaning insensibility). The zone of death may be known as the "olethric" zone (*ὀλέθριος*, meaning deadly). The region of greatest activity may be known as the "practicotatum" zone (*πρακτικώτατον*, meaning most effective).

Many phases of climatic effects have been differentiated, and medical literature abounds in words descriptive of these effects. For some effects no words are available. The writer has thought it best to present a complete and consistent system of nomenclature, based on the Greek, using all words already in the language, and only supplying new words where none are now available.[2]

It may be convenient to refer to the most effective temperature or the most effective humidity, in which cases we may use the words "thermopracticotatum" or "hygropracticotatum."

The awakening from sleep is termed "anastasis" (*ἀνάστᾶσις*). We can therefore speak of "thermanastasis" and "hygranastasis," depending on whether the awakening is caused by a change of temperature or a change of humidity.

Heat, moisture, dryness, or cold added to the "practicotatum" will cause sluggishness. We have to indicate this condition the term "nochelia"

[1] Hunter, W. D., Pratt, F. C., and Mitchell, J. D. The principal cactus insects of the United States, U. S. Dept. Agr. Bur. Ent. Bul. 113, p. 38–39. 1912.

[2] New Standard Dictionary. 1913.

Gould, G. M. An Illustrated Dictionary of Medicine, Biology and Allied Sciences . . . ed. 6, with . . . Sup . . . 1633, 571 p., Philadelphia, 1910.

(νωχέλεια, meaning sluggishness) and can show the type of sluggishness by the addition of a prefix, as "thermonochelia," "hygronochelia," "xeronochelia," and "rhigonochelia."

At least three of these factors produce under extreme conditions a stifling sensation, and we may express this by the terms "thermopnigia," "xeropnigia," and "hygropnigia" (πνίγος, meaning stifling).

The stifling sensation ends in complete insensibility, or anesthesia, and this word may be modified to express the cause, as in the term "thermanesthesia," "hygranesthesia," "xeranesthesia," and "rhiganesthesia."

Death from heat is known as thermoplegia (πληγή, meaning stroke), while from excessive moisture it may be known as "hygroplegia," and from freezing, as "rhigoplegia." Death from drying is known as "apoxeraenosis" (ἀποξηραίνω, meaning to dry up).

The determination of locomotion by heat is called "thermotaxis," and movement brought about by heat is called "thermotropism."

Unusual sensibility to heat is called "thermalgesia" and "hyperthermalgesia." The ability to recognize changes of temperature is "thermesthesia," and its extreme is designated as "thermohyperesthesia," abnormal sensitiveness to heat "stimuli." Fondness for heat or requiring great heat for growth is called "thermophilic," while resistance to heat is called "thermophylic." Rapid breathing, owing to high temperature, is designated as "thermopolypnea," contraction under the action of heat as "thermosystaltic," adapting the bodily temperature to that of the environment as "pecilothermal," and a morbid dread of heat as "thermophobia."

The life after apparent death, called "anabiosis," is exemplified in such cases as that of the Hermetia larvæ mentioned above.

Pain from the application of cold is called "cryalgesia," abnormal sensitiveness to cold "cryesthesia," and a morbid sensitiveness to cold "hypercryalgesia."

PRACTICAL APPLICATIONS

Many practical measures will result from the further study of climatic relations to life. A few of these may be indicated.

One of the most effective measures for the control of the cattle tick is pasture rotation based upon the possible duration of life of the seed tick without an animal host. As this period varies with the season, it is necessary to know the climatic laws under which this species reacts.

The fall army worm advances across the country and again retreats in complete accord with changing temperatures. The proper fixation of the zone of effective temperature may make it possible to plan the planting of winter crops to avoid damage.

The cotton boll weevil must have food up to the time that it enters hibernation. Early harvesting and destruction of stalks before the low temperatures set in offer one of the most satisfactory methods of control.

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY
SUBSCRIPTION PRICE, $3 PER YEAR

△

INDEX

Acer— Page
rubrum, host plant of *Comandra umbellata*.. 134
saccharinum, composition of sap of..... 538-540
saccharum—
composition of sap of..... 538-540
mineral composition of..... 539-542
Achillea millefolium, host plant of *Comandra umbellata*..... 134
Acid, fruit, toxicity of, to *Sclerotinia cinerea*.. 388
Actinomyces—
bovis, effect of low temperature on..... 654
chromogenus, effect of low temperature on..... 651-652, 654
organicus, effect of low temperature on... 651-652
Activity of Soil Protozoa (paper)..... 477-488
Aeration, effect of, on germination..... 1168
Age, relation of, to occurrence of tumors in domestic fowl..... 399
Agglutination Test as a Means of Studying the Presence of Bacterium abortus in Milk (paper)..... 871-875
Air, agency in dissemination of *Cercospora personata*..... 895-897
Alcohol, combustion of, in respiration calorimeter..... 345
Alfalfa. See *Medicago sativa*.
Alkali salts—
combinations of, effect on plant growth.... 13-48
effect of, on germination and growth of crops..... 1-53
toxicity of..... 1-53
Allard, H. A. (paper), Distribution of the Virus of the Mosaic Disease in Capsules, Filaments, Anthers, and Pistils of Affected Tobacco Plants..... 251-256
Alternaria—
panax, parasite of *Panax quinquefolium*.. 181-182
solani, effect of low temperature on..... 652
Alternaria panax, the Cause of a Rootrot of Ginseng (paper)..... 181-182
Alway, F. J., and Bishop E. S. (paper), Nitrogen Content of the Humus of Arid Soils 909-916
Amaranthus retroflexus, transpiration of.... 618-623
Ammonium hydroxid, effect of, on germination..... 1168-1169
Anaerobe—
facultative—
non-spore-forming..... 939
slime-forming..... 940
Andropogon—
sorghum, transpiration of..... 597-602
virginicus, host plant of *Comandra umbellata* 134
Angelica villosa, host plant of *Comandra umbellata*..... 134
Angular Leafspot of Cucumbers (paper)... 465-476
Anions, effect of, on growth of *Triticum* spp.. 42-43
Announcement of Weekly Publication..... i
Antennaria plantaginifolia, host plant of *Comandra umbellata*..... 134
Anthonomus grandis—
development of..... 1188-1189
relation of—
humidity to development of..... 1183-1191
temperature to development of..... 1183-1191
Apanteles militaris—
biology of..... 495-508
endoparasite of *Heliophila unipunctata*..... 493
function of caudal vesicle of..... 504-506
life stages of..... 495-501
origin of caudal vesicle of..... 504-506
Aphis, green apple. See *Aphis pomi*.
Aphis—
pomi—
biology of..... 955-994
diomorphic reproduction by..... 918
distribution of..... 957-958
egg stage of..... 960-967
feeding habits of..... 982-984
forms of..... 980-981
history of..... 957-958
life of stem mother of..... 968-970
methods of studying..... 958-960
morphology of..... 955-994
nomenclature of..... 956
overlapping generations of..... 981-982
sexes—
habits of..... 984-991
life of..... 984-991
summer forms of..... 970-978
spp., plan of description of..... 967-968
Apparatus for Measuring the Wear of Concrete Roads (paper)..... 951-954
Apple. See *Malus*.
Arachis hypogaea—
composition of seed of..... 1162
leafspot of..... 891-902
Army worm, fall. See *Laphygma frugiperda*.
Arsenic—
absorption of, by soil..... 460
applied as spray for weeds, fate and effect of..... 459-463
fixation reactions in soil..... 461-463
in soil, effect of irrigation on..... 460-461
Arrhenatherum elatius, syn. *Avena elatior*.
Ascochyta colorata, effect of low temperature on..... 654
Ash Composition of Upland Rice at Various Stages of Growth (paper)..... 357-364
Asiatic Species of Gymnosporangium Established in Oregon, An (paper)..... 1003-1010

Page

Asphalt—
cement. See Cement, asphalt.
effect of controllable variables upon the penetration test for 805–818
oil, results of needle standardization test .. 1123
Aster—
ericoides, host plant of *Comandra umbellata*. 134
macrophyllus, host plant of *Comandra umbellata* 134
patens, host plant of *Comandra umbellata* .. 134
undulatus, host plant of *Comandra umbellata* 134
Atriplex hortensis, host plant of *Peronospora effusa* 59, 67
Aubel, C. E., and Wentworth, E. N. (paper), Inheritance of Fertility in Swine 1145–1160
Automatic Transpiration Scale of Large Capacity for Use with Freely Exposed Plants, An (paper) 117–132
Avena—
eliator, host plant of *Puccinia phleipratensis* 212, 215
fatua, host plant of *Puccinia phleipratensis* 212–213
sativa—
absorption of boron by 884
composition of seeds of 1162
effect of—
alkali salts on growth of 24ff
green manure on germination of ... 1165–1166
on germination of various seeds 1163–1166
sulphur on the growth of 245–247
host plant of *Puccinia phleipratensis* ... 211–212
method of correcting for yields of 1041, 1045–1048
occurrence of manganese in 353
resistance of, to alkali 22–24
transpiration of 592–597
Avocado. See *Persea gratissima*.

Bacillus—
melonis, effect of low temperature on 654
tracheiphilus, parasite of *Cucumis sativus* ... 259
typhosus, effect of low temperature on 654
Back, E. A., and Pemberton, C. E. (paper)—
Banana as a Host Fruit of the Mediterranean Fruit Fly 793–804
Effect of Cold-Storage Temperatures upon the Mediterranean Fruit Fly 657–666
Bacteria—
effect of—
natural low temperature on 651–655
on germination 1171–1172
soil—
effect of—
calcium sulphate on 772–774
sulphur on 772–774
non-spore-forming 939
relation to crop-producing power 855–869
slime-forming 940
Bacterium—
abortus, agglutination test for in milk 871–875
lachrymans—
causal organism of angular leafspot 466–474
control of 474–475
geographical distribution of 467
identification and isolation of 466–467
morphology and physiology of 470–474

Page

Baker, A. C. (paper), Identity of Eriosoma pyri 1115–1119
Baker, A. C., and Turner, W. F. (paper), Morphology and Biology of the Green Apple Aphis 955–994
Balance—
automatic recording step-by-step 117–120
continuous-record 120–122
Ballinger, A. M., and Johnson, P. M. (paper) Life-History Studies of the Colorado Potato Beetle 917–926
Banana as a Host Fruit of the Mediterranean Fruit Fly (paper) 793–804
Banana. See also *Musa* spp.
Baptisia tinctoria, host plant of *Comandra umbellata* 134
Barley. See *Hordeum*.
Bartram, H. E. (paper), Effect of Natural Low Temperature on Certain Fungi and Bacteria 651–655
Bean—
See *Phaseolus vulgaris*.
Florida velvet. See *Stizolobium deeringianum*.
Philippine Lyon. See *Stizolobium niveum*.
Beef, mature—
comparison with immature veal 667–711
digestibility of 684–708
Beet, sugar. See *Beta vulgaris*.
Beetle—
blister. See *Epicauta vittata*.
cherry leaf. See *Galerucella cavicollis*.
Colorado potato. See *Leptinotarsa decemlineata*.
Belling, J. (paper), Inheritance of Length of Pod in Certain Crosses 405–420
Berg, W. N. (paper), Biochemical Comparisons between Mature Beef and Immature Veal 667–711
Beriberi and Cottonseed Poisoning in Pigs (paper) 489–493
Beta vulgaris—
absorption of boron by 880
effect of alkali salts on the growth of 4–6, 24ff
factors influencing—
infection by *Cercospora beticola* 1029–1037
stomatal movement in 1012–1029
histological relations of *Phoma betae* to 55–58
host plant of—
Cercospora beticola 1011–1038
Peronospora schachtii 59, 67
resistance of, to alkali 22–24
Betula—
nigra, host plant of *Comandra umbellata* 134
populifolia, host plant of *Comandra umbellata* 134
Biochemical Comparisons between Mature Beef and Immature Veal (paper) 667–711
Biology of Apanteles militaris (paper) 495–508
Bishop, E. S., and Alway, F. J. (paper), Nitrogen Content of the Humus of Arid Soils 909–916
Bituminous materials, test of, with new penetration needle 1121–1126
Blisterbeetle. See *Epicauta vittata*.
Boll weevil. See *Anthonomus grandis*.
Boron: Its Absorption and Distribution in Plants and Its Effect on Growth (paper). 877–890

Page

Bouyoucos, G. J. (paper), Effect of Temperature on Movement of Water Vapor and Capillary Moisture in Soils 141–172
Brassica—
alba—
composition of seed of 1162
effect of green manure on germination of. 1162
napus, effect of sulphur on growth of 243–245
nigra, host plant of *Cystopus candidus* 63
Briggs, L. J., and Shantz, H. L. (paper)—
An Automatic Transpiration Scale of Large Capacity for Use with Freely Exposed Plants 117–132
Hourly Transpiration Rate on Clear Days as Determined by Cyclic Environmental Factors 583–650
Bromus tectorum, host plant *Puccinia phlei-pratensis* 212–213, 215
Brown, P. E. (paper), Relation between Certain Bacterial Activities in Soils and Their Crop-Producing Power 855–869
Brownrot, varietal resistance of plums to.. 365–396
Bryan, M. K., and Smith, E. F., (paper), Angular Leafspot of Cucumbers 465–476
Buckner, G. Davis (paper), Translocation of Mineral Constituents of Seeds and Tubers of Certain Plants During Growth 449–458
Buckwheat. See *Fagopyrum tataricum*.

Calcium—
carbonate, effect of, on germination of seeds. 1170
sulphate—
effect of—
on forms of plant life 771–780
on growth of higher plants 775–778
on legume bacteria 774–775
Calorimeter, respiration—
air-purifying system in 305–310
air-tension equalizer in 304–305
description of 229–348
improved 299–348
principle of 301–302
Canal, irrigation—
computation of discharge of 226–231
use of current meters in 217–232
Cannabis sativa—
composition of seed of 1162
effect of green manure on germination of 1162–1166
Capillary moisture in soils, effect of temperature on movement of 141–172
Capsella bursa pastoris, host plant of *Cystopus candidus* 63, 67
Carbohydrate Transformations in Sweet Potatoes (paper) 543–560
Carbon dioxid, effect of, on germination 1169
Carex sp., host plant of *Comandra umbellata*.. 134
Carpenter, C. W. (paper), Some Potato Tuber-Rots Caused by Species of Fusarium 183–210
Carrero, J. O., and Gile, P. L. (paper), Ash Composition of Upland Rice at Various Stages of Growth 357–364
Carruth, F. E., and Withers, W. A. (paper), Gossypol, the Toxic Substance in Cottonseed Meal 261–288
Castanea dentata, host plant of *Comandra umbellata* 134

Page

Castilleja miniata, host plant of *Cronartium coleosporioides* 781–785
Castor bean. See *Ricinus communis*.
Cations, effect on growth of *Triticum* spp.... 42–43
Cats, experiments in feeding beef and veal to 703–708
Cement, asphalt—
characteristics of 805–807
effect of—
controllable variables upon the penetration test for 805–818
load variations on 815–816
temperature variation on 813–815
time variations on 816–817
methods of preparation for testing 807–813
Cephalothecium roseum, effect of low temperature on 652
Ceratitis capitata—
infestation of *Musa* spp. by 793–804
effect of cold-storage temperatures upon.. 657–666
parasite of—
Chrysophyllum cainto 657
Mangifera indica 657
Musa spp 793–804
Persea gratissima 657
presence of, in banana plantation 793–794
Cercospora—
beticola—
causal organism of leafspot 1011
factors influencing infection by 1029–1037
parasite of *Beta vulgaris* 1011–1038
relation of stomatal movement to infection by 1011–1038
personata—
casual organism of leafspot of *Arachis hypogaea* 891–902
control of 891–894
damage caused by 894–895
dissemination of 895–901
parasite of *Arachis hypogaea* 891–902
Chauliognathus sp., carrier of *Cercospora personata* 898–899
Cherry and Hawthorn Sawfly Leaf Miner (paper) 519–528
Cherry leaf beetle. See *Galerucella cavicollis*.
Chimaphila umbellata, host plant of *Comandra umbellata* 134
Chrysophyllum cainto, host fruit of *Ceratitis capitata* 657
Chrysopsis mariana, host plant of *Comandra umbellata* 134
Climate, relation of, to insect development.. 1184–1185, 1190–1191
Clover—
red. See *Trifolium pratense*.
See *Trifolium*.
sweet. See *Melilotus alba*.
Cold-storage temperatures, effect of, upon the Mediterranean fruit fly 657–666
Coleman, D. A., Lint, H. C., and Kopeloff, N. (paper), Separation of Soil Protozoa 137–140
Coleoptera, agency in dissemination of *Cercospora personata* 898–901
Colletotrichum lindemuthianum, effect of low temperature on 654

	Page
Comandra—	
livida, host plant of *Peridermium pyriforme*	133
pallida, host plant of *Peridermium pyriforme*	133
richardsiana, host plant of *Peridermium pyriforme*	133
umbellata—	
host plant of *Peridermium pyriforme*	133, 289
host plants of	134
parasitism of	133–135
Combination, new	1006
Comptonia peregrina, host plant of *Comandra umbellata*	134
Concrete roads, apparatus for measuring the wear of	951–954
Cone, V. M. (paper)—	
A New Irrigation Weir	1127–1136
Flow through Weir Notches with Thin Edges and Full Contractions	1051–1113
Cook, F. C. (paper), Boron: Its Absorption and Distribution in Plants and Its Effect on Growth	877–890
Cooledge, L. H. (paper), Agglutination Test as a Means of Studying the Presence of Bacterium abortus in Milk	871–875
Coons, C. H. (paper), Factors Involved in the Growth and Pycnidium Formation of Plenodomus fuscomaculans	713–769
Copper sulphate, effect on *Bacterium lachrymans*	474–475
Corn. See *Zea mays*.	
Cotton—	
See *Gossypium*.	
wild. See *Thurberia thespesioides*.	
Cottonseed—	
kernels, toxicity of	265–266, 278–283
meal—	
comparison with rice as a feed for pigs	490–492
effect of, on breeding sows	491–492
toxic substance in	261–268
poisoning in pigs, relation of, to beriberi	489–493
toxicity of	261–262, 283–286
Cowpea. See *Vigna sinensis*.	
Crataegus spp., host plants of *Profenusa collaris*	520–521
Cronartium—	
coleosporioides, parasite of *Castilleja minuata*	781
pyriforme, uredinial form of *Peridermium pyriforme*	289
Crop, effect of alkali salts in soils on germination and growth of	1–53
Crosses, inheritance of length of pod in	405–420
Cruciferae, effect of sulphur on	242–245
Cucumber. See *Cucumis sativus*.	
Cucumis sativus—	
angular leafspot of	465–476
host plant of—	
Bacillus tracheiphilus	259
Bacterium lachrymans	466–474
Plasmopara cubensis	259
Cucurbit, dissemination of bacterial wilt of	257–260
Curcuma longa, absorption of boron by	879
Current meter, use of, in irrigation canals	217–232
Curtis, Maynie R. (paper), Frequency of Occurrence of Tumors in the Domestic Fowl	397–404
Cydonia vulgaris, host plant of *Roestelia koreaensis*	1005
Cylindrosporium pomi, effect of low temperature on	652
Cystopus candidus—	
parasite of *Lepidium virginicum*	62–63, 67
perennial mycelium in	62–63, 67
Dactylis glomerata—	
host plant of *Puccinia phleipratensis*	211–215
Danthonia compressa, host plant of *Comandra umbellata*	134
Diabrotica vittata, agent in spread of bacterial wilt	257
Diastase—	
in apple flesh, results of tests for	109
presence of, in apple juice	108
Dipsacus fullonum, host plant of *Peronospora dipsaci*	59, 67
Dissemination of Bacterial Wilt of Cucurbits (paper)	257–260
Distribution of the Virus of the Mosaic Disease in Capsules, Filaments, Anthers, and Pistils of Affected Tobacco Plants (paper)	251–256
Diuresis and Milk Flow (paper)	561–568
Diuretics, effect of, on milk flow of goats	561–567
Dryrot—	
caused by—	
Fusarium eumartii	198–201
Fusarium radicicola	195–196
Edson, H. A. (paper), Histological Relations of Sugar-Beet Seedlings and Phoma betae	55–58
Effect of Alkali Salts in Soils on the Germination and Growth of Crops (paper)	1–53
Effect of Cold-Storage Temperatures upon the Mediterranean Fruit Fly (paper)	657–666
Effect of Controllable Variables upon the Penetration Test for Asphalts and Asphalt Cement (paper)	805–818
Effect of Elemental Sulphur and of Calcium Sulphate on Certain of the Higher and Lower Forms of Plant Life (paper)	771–780
Effect of Natural Low Temperature on Certain Fungi and Bacteria (paper)	651–655
Effect of Refrigeration upon the Larvæ of Trichinella spiralis (paper)	819–854
Effect of Temperature on Movement of Water Vapor and Capillary Moisture in Soils (paper)	141–172
Egg production of domestic fowl, measurement of winter cycle in	429–437
Elymus—	
canadensis, host plant of *Puccinia graminis avenae*	215
robustus, host plant of *Puccinia graminis avenae*	215
virginicus, host plant of *Puccinia phleipratensis*	212–213, 215
Emmer. See *Triticum dicoccum*.	
Emulsin, determination of, in flesh of *Malus sylvestris*	111
Endoparasite, caudal vesicle of	504–506
Environment—	
hourly transpiration rate on clear days as determined by	583–650
relation of, to transpiration of plants	637–646

Page
Enzyms of Apples and Their Relation to the Ripening Process (paper) ... 103-116
Epicauta vittata, carrier of *Cercospora personata* ... 898-899
Eriosoma pyri, identity of ... 1115-1119
Errata ... VII
Esterase, determination of, in flesh of *Malus sylvestris* ... 111, 112
Evaporation, ratio of transpiration to ... 634-637
Experiments in the Use of Current Meters in Irrigation Canals (paper) ... 217-232

Factors Influencing the Longevity of Soil Micro-organisms Subjected to Desiccation, with Special Reference to Soil Solution (paper) ... 927-942
Factors Involved in the Growth and Pycnidium Formation of Plenodomus fuscomaculans (paper) ... 713-769
Fagopyrum tataricum—
composition of seeds of ... 1162
effect of green manure on germination of ... 1162
Fate and Effect of Arsenic Applied as a Spray for Weeds (paper) ... 459-463
Fertility, swine—
inheritance of ... 1145-1160
nongenetic factors affecting ... 1146-1148
Fertilizer—
effect of, on North Carolina soils ... 577-581
requirements, relation of, to petrography of North Carolina soil ... 569-582
Field pea, Canada. See *Pisum arvense*.
Firefly. See *Chauliognathus* sp.
Flax. See *Linum usitatissimum*.
Float, surface, measurement of water velocity with ... 222-226
Flow through Weir Notches with Thin Edges and Full Contractions (paper) ... 1051-1113
Forest nurseries, disease in, caused by *Peridermium filamentosum* ... 781-785
Fowl, domestic—
frequency of occurrence of tumors in ... 397-404
measurement of winter cycle in egg production of ... 429-437
percentage of, affected with tumors ... 398
Fragaria—
americana, host plant of *Comandra umbellata* ... 134
virginiana, host plant of *Comandra umbellata* ... 134
Fred, E. B. (paper), Relation of Green Manures to Failure of Certain Seedlings ... 1161-1176
Frequency of Occurrence of Tumors in the Domestic Fowl (paper) ... 397-404

Fungus—
effect of—
natural low temperature on ... 651-655
on germination of seeds ... 1172-1174
Further Studies on Peanut Leafspot (paper) ... 891-902
Fusarium—
coeruleum—
diagnostic characters of ... 203-204
parasite of *Solanum tuberosum* ... 184
taxonomic arrangement of ... 203-204
culmorum, parasite of *Solanum tuberosum* ... 184
Fusarium—Continued. Page
discolor var. *sulphureum*—
diagnostic characters of ... 207
parasite of *Solanum tuberosum* ... 184-185
taxonomic arrangement of ... 207
eumartii—
cause of dryrot ... 198-201
diagnostic characters of ... 203-205
taxonomic arrangement of ... 203-205
gibbosum, parasite of *Solanum tuberosum* ... 184
hyperoxysporum—
diagnostic characters of ... 206
parasite of *Ipomoea batatas* ... 189
taxonomic arrangement of ... 206
martii, parasite of *Solanum tuberosum* 186, 201-203
moniliforme, parasite of *Solanum tuberosum* ... 186, 201, 203
orthoceras, parasite of *Solanum tuberosum* ... 184
oxysporum, parasite of *Solanum tuberosum* 187-191
radicicola—
cause of—
dryrot ... 195, 196
jelly-end rot ... 194-195
diagnostic characters of ... 205-206
taxonomic arrangement of ... 203, 205-206
rubignosum, syn. *Fusarium culmorum*.
solani—
parasite of *Solanum tuberosum* ... 186, 188, 189, 201, 203
diagnostic characters of ... 203-204
taxonomic arrangement of ... 203-204
sp. of conifers, effect of low temperature on ... 652
spp. —
results of inoculation of *Solanum tuberosum* with ... 201-203
causal organism of potato tuber-rot ... 183-210
subulatum, parasite of *Solanum tuberosum* ... 184
trichothecioides—
diagnostic characters of ... 207
parasite of *Solanum tuberosum* ... 184, 185
taxonomic arrangement of ... 207
vasinfectum, parasite of *Solanum tuberosum* ... 186, 192-194
ventricosum, parasite of *Solanum tuberosum* ... 184

Galerucella cavicollis—
control of ... 949
habits of ... 945-948
life history of ... 945-948
outbreaks ... 944
parasite of *Prunus pennsylvanica* ... 944
Gas, residual, determination of, in respiration calorimeter ... 310-314
Gaylussacia frondosa. host plant of *Comandra umbellata* ... 134
Germination—
effect of—
aeration on ... 1168
ammonium hydroxid on ... 1168-1169
bacteria on ... 1171-1172
carbon dioxid on ... 1169
fungi on ... 1172-1174
green manure on ... 1161-1165
heat on ... 1170-1171
position of green manure on ... 1167
soil type on ... 1167
temperature on ... 1168
time of planting on ... 1164-1165

Page

Gile, P. L., and Carrero, J. O. (paper), Ash Composition of Upland Rice at Various Stages of Growth 357-364
Giltner, W., and Langworthy, H. V. (paper), Some Factors Influencing the Longevity of Soil Micro-organisms Subjected to Desiccation, with Special Reference to Soil Solution 927-942
Ginseng. See *Panax quinquefolium*.
Glomerella rufomaculans, effect of low temperature on 652
Glycine—
hispida, absorption of boron by 883-884
soja—
composition of seeds of 1162
effect of green manure on germination of 1164-1166
Goat, effect of diuretics on milk flow of 561-567
Goldbeck, A. T. (paper), Apparatus for Measuring the Wear of Concrete Roads 951-954
Gossypium—
herbaceum—
composition of seeds of 1162
effect of—
fungi on germination of 1172-1174
green manure on germination 1163-1167, 1170
heat on germination of 1170-1171
temperature on germination of 1168, 1170-1171
time of planting on germination of. 1164-1165
spp.—
toxicity of seeds of 261-262
yields of, in North Carolina soils 578-580
Gossypol—
acetate, crystalline, toxicity of 273-278
extract, toxicity of 266-267
method of—
feeding 265, 267-270
preparation 262-263
occurrence of 264-263
oxidized, toxicity of 278-281
post-mortem observations of, effects of administering 270, 273-275
precipitated, toxicity of 271-272
properties of 264-265
Gossypol, the Toxic Substance in Cottonseed Meal (paper) 261-288
Gramineae, effect of sulphur on 245-247
Grape, wild. See also *Vitis cordifolia*.
Grasshopper, carrier of *Cercospora personata* 898-900
Green manure. See Manure, green.
Gymnosporangium, an Asiatic species of, established in Oregon 1003-1010
Gymnosporangium—
asiaticum, hyponym, *Gymnosporangium koreaense*.
Blasdaleanum, economic importance of 1007-1008
chinense, syn. *Gymnosporangium koreaense*.
Haraeanum—
parasite of *Juniperus chinensis* 1005
syn. *Gymnosporangium koreaense*.
japonicum, syn. *Gymnosporangium koreaense*.
juniperi-virginianae, economic importance of 1007-1008

Gymnosporangium—Continued. Page
koreaense—
description of 1006-1007
economic importance of 1007-1008
photiniae—
description of 1007
economic importance of 1008

Harding, S. T. (paper), Experiments in the Use of Current Meters in Irrigation Canals 217-232
Harris, Frank S. (paper), Effect of Alkali Salts in Soils on the Germination and Growth of Crops 1-53
Hart, E. B., and Tottingham, W. E. (paper), Relation of Sulphur Compounds to Plant Nutrition 233-250
Harter, L. L. (paper), Sweet-Potato Scurf. 787-791
Hasselbring, H., and Hawkins, L. A. (paper): Carbohydrate Transformations in Sweet Potatoes 543-560
Respiration Experiments with Sweet Potatoes 509-517
Hawkins, L. A., and Hasselbring, H. (paper): Carbohydrate Transformations in Sweet Potatoes 543-560
Respiration Experiments with Sweet Potatoes 509-517
Hawthorn sawfly leaf miner. See *Profenusa collaris*.
Headden, W. P. (paper), Occurrence of Manganese in Wheat 349-355
Heartrot—
honeycomb—
character of, in *Quercus alba* 422-424
distribution of 427-428
in *Quercus* spp 421-428
resemblance to other rots 424-425
pocketed. See Honeycomb heartrot.
Hedgcock, G. G. (paper), Parasitism of Comandra umbellata 133-135
Hedgcock, G. G., and Long, W. H. (paper), Two New Hosts for Peridermium pyriforme 289-290
Helianthus—
annuus—
composition of seeds of 1162
effect of green manure on germination of. 1162
divaricatus, host plant of *Plasmopara halstedii* 65, 66, 67
Heliophila unipunctata, host of *Apanteles militaris* 49
Heliothis obsoleta, agency in dissemination of *Cercospora personata* 898-899
Hemiptera, agency in dissemination of *Cercospora personata* 898-901
Hemp. See *Cannabis sativa*.
Hepatica acutiloba, host plant of *Plasmopara pygmaea* 67
Herrick, G. W., and Matheson, R. (paper), Observations on the Life History of the Cherry Leaf Beetle 943-950
Heterogeneity, soil, in variety tests, method of correcting for 1039-1050
Hibernation of Phytophthora infestans in the Irish Potato (paper) 71-102
Hieracium venosum, host plant of *Comandra umbellata* 134

Page

Histological Relations of Sugar-Beet Seedlings and Phoma betae (paper)..... 55–58
Honeycomb heartrot—
character of, in *Quercus alba*..... 422–424
control of..... 428
distribution of..... 427–428
resemblance of, to other rots..... 424–425
Honeycomb Heartrot of Oaks Caused by Stereum subpileatum (paper)..... 421–428
Hordeum—
sp., occurrence of manganese in..... 353
spp.—
effect of alkali salts on growth of..... 23ff
resistance of, to alkali..... 22–24
vulgare—
effect of sulphur on growth of..... 245
test of inoculation with *Puccinia phleipratensis*..... 211–212
Hourly Transpiration Rate on Clear Days as Determined by Cyclic Environmental Factors (paper)..... 583–650
Houston, D. F., Announcement of Weekly Publication..... i
Hubbard, P., and Jackson, F. H., jr. (paper), Relation Between the Properties of Hardness and Toughness of Road-Building Rock..... 903–907
Hubbard, P., and Pritchard, F. P. (paper), Effect of Controllable Variables upon the Penetration Test for Asphalts and Asphalt Cements..... 805–818
Hubert, E. E., and Weir, J. R. (paper), A Serious Disease in Forest Nurseries Caused by Peridermium filamentosum..... 781–785
Humidity, relationship of, to insect development..... 1183–1191
Humus—
of arid soils, nitrogen content of..... 909–916
relation of, to nitrogen in California soils.. 914–915

Identity of Eriosoma pyri (paper)..... 1115–1119
Improved Respiration Calorimeter for Use in Experiments with Man, An (paper)..... 299–348
Inactivity, zone of, in insect development..... 1189–1190
Infection by *Cercospora beticola*, relation of stomatal movement to..... 1011–1038
Infection Experiments with Timothy Rust (paper)..... 211–216
Influence of Growth of Cowpeas upon Some Physical, Chemical, and Biological Properties of Soil (paper)..... 439–448
Inheritance of Fertility in Swine (paper). 1145–1160
Inheritance of Length of Pod in Certain Crosses (paper)..... 405–420
Insect—
agency in dissemination of *Cercospora personata*..... 897–901
development—
climatic relations in..... 1184–1185
relationships of temperature and humidity to..... 1173–1181
nomenclature of climatic effects on life of... 1190–1191
zone of inactivity in development of... 1189–1190
Invertase in apple flesh, results of tests for.. 109–111

Page

Ionactis linariifolius, host plant of *Comandra umbellata*..... 134
Ipomoea batatas—
analyses of..... 545–557
carbohydrate transformations in..... 543–560
host plant of *Monilochaetes infuscans*.... 787–791, 995–1002
respiration experiments with..... 509–517
scurf of..... 787–791
storage experiments with..... 997
variations in composition of..... 510–516
Irrigation—
canal, experiments in use of current meters in..... 217–232
effect of, on arsenic in soil..... 460–461
weir, a new..... 1127–1136

Jackson, F. H., Jr., and Hubbard, P. (paper), Relation Between the Properties of Hardness and Toughness of Road-Building Rock..... 903–907
Jackson, H. S. (paper), An Asiatic Species of Gymnosporangium Established in Oregon..... 1003–1010
Jelly-end rot, caused by *Fusarium radicicola*. 194–195
Jensen, L., and Stakman, E. C. (paper), Infection Experiments with Timothy Rust. 211–216
Johnson, P. M., and Ballinger, A. M. (paper), Life-History Studies of the Colorado Potato Beetle..... 917–926
Juniperus chinensis, host plant of *Gymnosporangium Haraeanum*..... 1005

Kamani nut. See *Terminalia catappa*.
Katydid, agency in dissemination of *Cercospora personata*..... 898, 900
Koch, George P. (paper), Activity of Soil Protozoa..... 477–488
Kopeloff, N., Lint, H., and Coleman, D. A. (paper), Separation of Soil Protozoa..... 137–140

Lactuca sativa, absorption of boron by..... 879–882
Lady beetle. See *Megilla maculata*.
Langworthy, H. V., and Giltner, W. (paper), Some Factors Influencing the Longevity of Soil Micro-organisms Subjected to Desiccation, with Special Reference to Soil Solution..... 927–942
Laphygma frugiperda, periods of activity of... 1189
Leaf—
hopper, carrier of *Cercospora personata*... 898, 900
maturity, definition of..... 1011
miner, sawfly. See *Profenusa collaris*.
Leafspot—
angular, of *Cucumis sativus*..... 465–476
injury to *Arachis hypogaea*..... 894–895
occurrence on—
Arachis hypogaea..... 891–902
Beta vulgaris..... 1011
Le Clair, C. A. (paper), Influence of Growth of Cowpeas upon Some Physical, Chemical, and Biological Properties of Soil..... 439–448
Lepidium virginicum—
host plant of—
Cystopus candidus..... 67
Peronospora parastica..... 60–63, 67

Page

Lepidoptera, agency in dissemination of *Cercospora personata*..... 898-901
Leptinotarsa decemlineata—
eggs produced by..... 919-922
life history of..... 917-926
Lespedeza violacea, host plant of *Comandra umbellata*..... 134
Lettuce. See *Lactuca sativa*.
Life-History Studies of the Colorado Potato Beetle (paper)..... 917-926
Lint, H. C., Kopeloff, N., and Coleman, D. A. (paper), Separation of Soil Protozoa..... 137-140
Linum usitatissimum, composition of seed of.. 1162
Liquidambar styraciflua, host plant of *Stereum subpileatum*..... 427
Litter, inheritance of size of, studies in.... 1149-1150
Lodgepole pine. See *Pinus murrayana*.
Lolium—
italicum, host plant of *Puccinia phleipratensis*..... 212-213, 215
perenne, host plant of *Puccinia phleipratensis*..... 212-213, 215
Long, W. H. (paper), Honeycomb Heartrot of Oaks Caused by Stereum subpileatum. 421-428
Long, W. H., and Hedgcock, G. G. (paper), Two New Hosts for Peridermium pyriforme..... 289-290
Lupine, white. See *Lupinus albus*.
Lupinus albus—
composition of seeds of..... 1162
effects of green manure on germination of. 1162
Lycopersicon esculentum, absorption of boron by..... 881-882
Lyon bean. See *Stizolobium niveum*.
Lysimachia quadrifolia, host plant of *Comandra umbellata*..... 134

McGeorge, W. T. (paper), Fate and Effect of Arsenic Applied as a Spray for Weeds.. 459-463
McKay, M. B., and Pool, V. W. (paper), Relation of Stomatal Movement to Infection by Cercospora beticola..... 1011-1038
Magnesium salts, effect of, on plant growth.. 5-6, 8-10, 16ff
Malus spp.—
changes in chemical composition during ripening..... 105-106
host fruit of *Ceratitis capitata*..... 659
host plant of—
Monilia fructigena..... 365-367
Plenodomus fuscomaculans..... 713
Sclerotinia spp..... 365
relation of enzyms to ripening process of. 103-116
Manganese, occurrence of, in wheat..... 349-355
Mangifera indica, host fruit of *Ceratitis capitata*..... 657
Mango. See *Mangifera indica*.
Manure, green—
effect of, on seed germination..... 1161-1165
nature of injurious agent in..... 1166
relation of—
to failure of seedlings..... 1161-1176
to injury of oil seeds..... 1174
Maple—
sugar. See *Acer saccharum*.
water. See *Acer saccharinum*.

Page

Massee, views on origin of *Phytophthora infestans*..... 96-97
Matheson, R., and Herrick, G. W. (paper) Observations on the Life History of the Cherry Leaf Beetle..... 943-950
Meal, cottonseed, toxic substance in..... 261-288
Measurement of the Winter Cycle in the Egg Production of Domestic Fowl (paper).. 429-437
Medicago sativa—
effect of alkali salts on growth of..... 25ff
resistance of, to alkali..... 22-24
use of, as a diuretic..... 561
Mediterranean fruit fly. See *Ceratitis capitata*.
Megilla maculata, agency in dissemination of *Cercospora personata*..... 898-900
Meibomia paniculata, host plant of *Comandra umbellata*..... 134
Melhus, I. E. (paper)—
Hibernation of Phytophthora infestans in the Irish Potato..... 71-102
Perennial Mycelium in Species of Peronosporaceae Related to Phytophthora infestans..... 59-70
Meter, current, experiments in use in irrigation canals..... 217-232
Method of Correcting for Soil Heterogeneity in Variety Tests, A (paper)..... 1039-1050
Micro-organism, soil, factors influencing the longevity of..... 927-942
Milk—
agglutination test for presence of *Bacterium abortus* in..... 871-875
flow, effect of diuresis on..... 561-568
Milner, R. D., and Langworthy, C. F. (paper), An Improved Respiration Calorimeter for Use in Experiments with Man..... 299-348
Miner, leaf, sawfly. See *Profenusa collaris*.
Mineral constituents, translocation of, in seeds and tubers of plants..... 449-458
Moisture—
and temperature, relation of, to spread of mycelium of *Phytophthora infestans* in tubers..... 73
capillary, effect of temperature on movement of, in soils..... 141-172
movement of, between warm and cold soils..... 141-172
soil, description of apparatus for determining translocation of..... 142-144
Monilia—
fructigena, parasite of *Malus* spp..... 365, 367
laxa, parasite of apricot..... 365
Monilochaetes—
infuscans—
causal organism of soilstain..... 998
description of..... 789-791, 1000
distribution of..... 787
inoculation experiments with..... 788-789
isolation of..... 788
loss due to..... 788
morphology of..... 998-1000
parasite of *Ipomoea batatas*.. 787-791, 995-1002
physiology of..... 998-1000
taxonomy of..... 790-791, 10000
technical description of genus..... 791

Page

Morphology and Biology of the Green Apple Aphis (paper) ... 955-994
Mosaic disease—
distribution of the virus of ... 251-256
occurrence of virus in plants of *Nicotiana tabacum* ... 254
virus of, in placental structure of plants of *Nicotiana tabacum* ... 253-253
Movement of moisture from warm to cold soil ... 141-156
Mucor sp., parasite of *Solanum tuberosum* ... 186, 201-203
Musa spp.—
green fruits of, immunity of, to attack by *Ceratitis capitata* ... 799-801
immunity of, to attack by *Ceratitis capitata* 793-804
Muscular work, apparatus for measuring ... 342-343
Mustard, white. See *Brassica alba.*

Needle, penetration—
use of, in testing bituminous materials. 1121-1126
results of standardization test of ... 1123
results of tests of ... 1124-1126
New Interpretation of the Relationships of Temperature and Humidity to Insect Development, A (paper) 1183-1191
New Irrigation Weir, A (paper) ... 1127-1136
New Penetration Needle for Use in Testing Bituminous Materials, A (paper) ... 1121-1126
New Spray Nozzle, A (paper) ... 1177-1182
Nicotiana tabacum, distribution of the virus of the mosaic disease in ... 251-256
Nitrate production—
effect of—
calcium sulphate on ... 774-775
sulphur on ... 774-775
Nitrogen Content of the Humus of Arid Soils (paper) ... 909-916
Nitrogen—
humus, methods for determining ... 911-913
relation of, to humus in California soils ... 914-915
North Carolina, petrography of soils of ... 569-577
Nozzle, spray, a new ... 1177-1182
Nursery, forest, disease in, caused by *Peridermium filamentosum* ... 781-785
Nutrition, plant, relation of sulphur compounds to ... 233-250

Oak, white. See *Quercus alba.*
Oats. See *Avena sativa.*
Observations on Life History of the Cherry Leaf Beetle (paper) ... 943-950
Occurrence of Manganese in Wheat (paper). 349-355
Oospora scabies, syn. *Actinomyces chromogenus.*
Orthoptera, agency in dissemination of *Cercospora personata* ... 898-901
Oryza sativa, ash analyses of ... 359-363
Oskamp, J. (paper), Soil Temperatures as Influenced by Cultural Methods ... 173-179
Oxidases, determination of, in flesh of *Malus sylvestris* ... 112-113

Panax quinquefolium—
blackrot of ... 294-296
host plant of—
Alternaria panax ... 181-182
Phytophthora cactorum ... 59, 67
Sclerotinia libertiana ... 291

Panax quinquefolium—Continued. Page
inoculation of, with *Sclerotinia libertiana* from various sources ... 292-293
pathogenicity and identity of *Sclerotinia libertiana* and *Sclerotinia smilacina* on ... 291-298
rootrot of ... 181-182
whiterot of ... 291-294
Panicum sp., host plant of *Comandra umbellata* ... 134
Parasitism of Comandra umbellata (paper). 133-135
Pathogenicity and Identity of Sclerotinia libertiana and Sclerotinia smilacina on Ginseng (paper) ... 291-298
Pea—
See *Pisum sativum.*
Canada field. See *Pisum arvense.*
Peanut. See *Arachis hypogaea.*
Pearl, R. (paper), Measurement of the Winter Cycle in the Egg Production of Domestic Fowl ... 429-437
Pearl, R., and Surface, F. M. (paper), A Method of Correcting for Soil Heterogeneity in Variety Tests ... 1039-1050
Pectinase, determination of, in flesh of *Malus sylvestris* ... 114-115
Pemberton, C. E., and Back, E. A. (paper)—
Banana as a Host Fruit of the Mediterranean Fruit Fly ... 793-804
Effect of Cold-Storage Temperatures upon Mediterranean Fruit Fly ... 657-666
Penetration test, asphalt, effect of controllable variables upon ... 805-818
Perennial Mycelium in Species of Peronosporaceae Related to Phytophthora infestans (paper) ... 59-70
Peridermium—
cerebrum, parasite of *Pinus divaricata* ... 289
complanatae, parasite of *Pinus (murrayana) contorta* ... 290
filamentosum—
causal organism of disease in forest nurseries ... 781-785
parasite of—
Castilleja miniata ... 781-785
Pinus contorta ... 783
Pinus ponderosa ... 781
montanum, parasite of *Pinus murrayana* ... 785
pyriforme—
æcial form of *Cronartium pyriforme* ... 289
parasite of—
Comandra umbellata ... 289
Pinus arizonica ... 290
Pinus divaricata ... 133, 289-290
Pinus (murrayana) contorta ... 133, 289-290
Pinus ponderosa ... 133
Pinus ponderosa scopulorum ... 133, 290
Pinus pungens ... 133, 290
Pinus rigida ... 133, 289-290
two new hosts for ... 289-290
spp., parasites of *Quercus* spp ... 783
Peronosporaceae, relation of perennial mycelium in, to *Phytophthora infestans* ... 59-70
Peronospora—
alsinearum, parasite of *Stellaria media* ... 59, 67, 68
dipsaci, parasite of *Dipsacus fullonum* ... 59, 67
effusa—
parasite of—
Atriplex hortensis ... 59, 67
Spinacia oleracea ... 59, 67, 68

Peronospora—Continued. Page
ficariae—
parasite of *Ranunculus ficaria*..... 64, 67
perennial mycelium in..... 64, 67
grisea, parasite of *Veronica lederaefolia*... 59, 67, 68
parasite of *Lepidium virginicum*..... 60–62, 67
parasitica—
perennial mycelium in..... 60–62, 67
rumicis, parasite of *Rumex acetosa*..... 67
schachtii, parasite of *Beta vulgaris*..... 59, 67
viciae—
parasite of *Vicia sepium*..... 67, 64–65
perennial mycelium in..... 64–65, 67
Persea gratissima, host fruit of *Ceratitis capitata*..... 657
Petrography of Some North Carolina Soils and Its Relation to Their Fertilizer Requirements (paper)..... 569–582
Pezoporus tenthredinarum, parasite of *Profenusa collaris*..... 527
Phaseolus vulgaris—
absorption of boron by..... 883–885
analysis of seeds and seedlings of..... 452
effect of sulphur on growth of..... 238–239
translocation of mineral constituents of.. 450–454
Phleum—
asperum, host plant of *Puccinia graminis avenae*..... 213
pratense, host plant of *Puccinia phleipratensis*..... 212
Phalaris canariensis, host plant of *Puccinia graminis avenae*..... 212–213
Phoma betae, histological relations to seedlings of *Beta vulgaris*..... 55–58
Physical factors, relation to transpiration.. 585–623
Phytophthora—
infestans—
development of epidemics of..... 89–92
epidemics of, caused by infected seed potatoes..... 80–85
hibernation of, in Irish potato..... 71–102
infection renewed by soil-borne conidia of. 97–98
influence of temperature on growth of... 77–80
mycelium of in the soil..... 96
origin of..... 96–97
parasite of *Solanum tuberosum*..... 59, 67, 183
perpetuation of..... 97
relation of perennial mycelium in species of Peronosporaceae to..... 59–70
resting spores of..... 98–99
omnivora, effect of low temperature on..... 654
Pierce, W. D. (paper), A New Interpretation of the Relationships of Temperature and Humidity to Insect Development..... 1183–1191
Pig, poisoning of, by cottonseed..... 489–493
Pine. See *Pinus*.
Pinus—
contorta—
host plant of—
Peridermium filamentosum..... 783
Peridermium pyriforme..... 133, 289–290
divaricata—
host plant of *Peridermium pyriforme*... 133, 290
murrayana, host plant of *Peridermium montanum*..... 785
ponderosa—
host plant of *Peridermium filamentosum*..... 133, 781
scopulorum, host plant of *Peridermium pyriforme*..... 133, 290
Pinus—Continued. Page
pungens, host plant of *Peridermium pyriforme*..... 133, 290
rigida, host plant of *Peridermium pyriforme*..... 133, 289, 290
Pisum—
arvense, effect of alkali salts on growth of..... 22–24, 25ff
sativum—
absorption of boron by..... 884–885
effect of sulphur on growth of..... 241–242
Pitz, W. (paper), Effect of Elemental Sulphur and Calcium Sulphate on Certain of the Higher and Lower Forms of Plant Life.. 771–780
Plasmopara—
cubensis, parasite of *Cucumis sativus*..... 259
halstedii—
parasite of *Helianthus divaricatus*..... 65–66, 67
perennial mycelium in..... 65–67
pygmaea, parasite of *Hepatica acutiloba*..... 59, 67
viticola, parasite of *Vitis vinifera*..... 67
Plenodomus fuscomaculans—
conditions of growth and reproduction of. 720–764
effect of—
acidity and alkalinity on..... 734–737
aeration on..... 727–730
air circulation on..... 724
change of intensity of a factor on..... 754–758
humidity in..... 730–734
light on..... 720–725
quality of food on..... 742–754
quantity of food on..... 737–742
temperature on..... 725–727
growth of..... 713–769
parasite of *Malus sylvestris*..... 713
pycnidium formation of..... 713–769
Plowrightia morbosa, effect of low temperature on..... 652
Plum. See *Prunus*.
Plummer, J. K. (paper), Petrography of Some North Carolina Soils and Its Relation to their Fertilizer Requirements..... 569–582
Poa—
compressa, host plant of *Comandra umbellata*..... 134
pratensis, host plant of *Comandra umbellata*..... 134
Pocketed heartrot. See Honeycomb heartrot.
Pod, inheritance of length of, in certain crosses..... 405–420
Pool, V. W., and McKay, M. B. (paper), Relation of Stomatal Movement to Infection by Cercospora beticola..... 1011–1038
Populus tremuloides, host plant of *Comandra umbellata*..... 134
Potassium salts, effect on plant growth... 5–6, 16ff
Potato—
beetle, Colorado. See *Leptinotarsa decemlineata*.
Irish. See *Solanum tuberosum*.
sweet. See *Ipomoea batatas*.
tuber-rots..... 183–210
Potentilla monspeliensis, host plant of *Comandra umbellata*..... 134
Pritchard, F. P., and Hubbard, P. (paper), Effect of Controllable Variables upon the Penetration Test for Asphalts and Asphalt Cements..... 805–818

Page

Pritchard, F. P., and Reeve, C. S. (paper), A New Penetration Needle for Use in Testing Bituminous Materials 1121–1126

Prociphilus—
aceris, description of 1118
alnifoliae, description of 1118
bumulae, description of 1118
corrugatans, description of 1118
fraxini-depetalae, syn. *Prociphilus venafuscus* .....
imbricator, description of 1118
populiconduplifolius, description of 1118
poschingeri, description of 1119
pyri, description of 1116, 1118
tessellatus, description of 1119
venafuscus, description of 1119
xylostei, description of 1119

Profenusa collaris—
control of 527–528
description of 522–524
distribution of 520–522
enemies of 526–527
habits of 524–526
injury to *Prunus* spp. by 521–522
life history of 524–526
parasite of—
Crataegus spp 519–520
Prunus spp 519–520

Protease, determination of, in flesh of *Malus sylvestris* 113–114

Protozoa, soil—
activity of 477–488
encystment of 485–487
separation of 137–140

Prunus—
pennsylvanica, host plant of *Galerucella cavicollis* 944
spp.—
host plant of—
Monilia spp 365
Profenusa collaris 519–520
Sclerotinia spp 365–366
hybrids used in experiments with brownrot 369–370
relation of tannin content of, to resistance to *Sclerotinia* spp 389–390
resistance of, to brownrot 369, 379–383, 387
susceptibility of, to brownrot 387
varietal resistance of, to brownrot 365–396

Pseudomonas—
campestris, effect of low temperature on 654
radicicola, longevity of, under varying conditions 932–940

Puccinia—
graminis—
avenae, parasite of cereals and grasses .. 213, 215
hordei, parasite of grasses and cereals ... 213, 215
phleipratensis, infection experiments with 211–216

Pycnidium formation in *Plenodomus fuscomaculans* 713–769

Pyrus—
communis, host plant of *Roestelia koreaensis*. 1005
sinensis, host plant of *Roestelia koreaensis* 1005–1006

Quercus—
alba, character of honeycomb heartrot in . 422–424
coccinea, host plant of *Comandra umbellata* .. 134

Quercus—Continued. Page
digitata, host plant of *Comandra umbellata* .. 134
marilandica, host plant of *Comandra umbellata* 134
nana, host plant of *Comandra umbellata* 134
spp.—
honeycomb heartrot of 421–428
host plant of—
Peridermium spp 783
Polyporus spp 421
Stereum subpileatum 421, 427–428

Radish. See *Raphanus sativus*.

Rand, F. V. (paper), Dissemination of Bacterial Wilt of Cucurbits 257–260

Ransom, B. H. (paper), Effects of Refrigeration upon the Larvae of Trichinella spiralis 819–854

Ranunculus—
fascicularis, host plant of *Peronospora ficariae* 59, 64, 67
ficaria, host plant of *Peronospora ficariae* ... 64, 67

Rape. See *Brassica napus*.

Raphanus sativus—
absorption of boron by 885
effect of sulphur on growth of 242–243

Record, autographic transpiration 128–130

Reeve, C. S., and Pritchard, F. P. (paper), A New Penetration Needle for Use in Testing Bituminous Materials 1121–1126

Refrigeration, effect of, upon larvae of *Trichinella spiralis* 819–854

Relation between Certain Bacterial Activities in Soils and Their Crop-Producing Power (paper) 855–869

Relation between the Properties of Hardness and Toughness of Road-Building Rock (paper) 903–907

Relation of Green Manures to the Failure of Certain Seedlings (paper) 1161–1176

Relation of Stomatal Movement to Infection by Cercospora beticola (paper) 1011–1038

Relation of Sulphur Compounds to Plant Nutrition (paper) 233–250

Resistance, varietal, of plums to brownrot .. 365–396

Respiration—
calorimeter—
conditions affecting and measurement of heat in 315–342
improved 299–348
test of accuracy of 344–346
chamber, construction of 302–304

Respiration Experiments with Sweet Potatoes (paper) 509–517

Respiratory exchange in respiration chamber, determination of 304–314

Rhizoctonia sp.—
effect of, on germination 1173–1174
parasite of *Solanum tuberosum* 186, 201, 202

Rhizopus nigricans, parasite of *Solanum tuberosum* 183

Rhus copallina, host plant of *Comandra umbellata* 134

Rice—
polished, effect of feeding to pigs 490–492
See also *Oryza sativa*.
upland, ash composition of, at various stages of growth 357

Ricinus communis, composition of seed of ... 1162

Page

Riperot, occurrence of, in *Prunus* spp..... 388–389
Road, concrete, apparatus for measuring the wear of..... 951–954
Roasting-ear worm. See *Heliothis obsoleta.*
Rock, road-building—
relation between the properties of hardness and toughness of..... 903–907
tests of..... 903–907
Roestelia—
koreaensis—
occurrence of—
in America..... 1004–1006
in Japan..... 1004
in Oregon..... 1005–1006
parasite of—
Cydonia vulgaris..... 1005
Pyrus sinensis..... 1003–1006
relation of, to *Gymnosporangium koreaense*. 1004–1006
photiniae, syn. *Gymnosporangium photiniae.*
Rommel, G. M., and Vedder, E. B. (paper), Beriberi and Cottonseed Poisoning in Pigs. 489–493
Rootrot, occurrence of, in *Panax quinquefolium*..... 181–182
Rosa—
blanda, host plant of *Comandra umbellata*... 134
canina, host plant of *Comandra umbellata*... 134
Rosenbaum, J. (paper), Pathogenicity and Identity of Sclerotinia libertiana and Sclerotinia smilacina on Ginseng..... 291–298
Rosenbaum, J., and Zinnsmeister, C. L. (paper), Alternaria panax, the Cause of a Rootrot of Ginseng..... 181–182
Rot—
brown, varietal resistance of plums to ... 365–396
dry, caused by *Fusarium* spp 195–201
field and storage, occurrence of, in *Solanum tuberosum*..... 187–201
heart—
honeycomb—
distribution of..... 427–428
occurrence of, in *Quercus* spp..... 421–428
resemblance to other rots..... 424–425
pocketed. See Honeycomb heartrot.
jelly-end, caused by *Fusarium radicicola*. 194–195
ripe, occurrence of, in *Prunus* spp 388–389
root, occurrence of, in *Panax quinquefolium*. 181–182
white, occurrence of, in *Panax quinquefolium* 291–294
Rubus—
canadensis, host plant of *Comandra umbellata*..... 134
procumbens, host plant of *Comandra umbellata*..... 134
villosus, host plant of *Comandra umbellata*.. 134
Rumex acetosa, host plant of Peronospora *rumicis*..... 67
Rust, timothy. See *Puccinia phleipratense.*
Rye. See *Secale cereale.*

Salt, alkali, in soils, effect of, on germination and growth of crops..... 1–53
Sawfly leaf miner. See *Profenusa collaris.*
Scale, automatic transpiration, description of..... 117–132
Sclerotinia— Page
cinerea—
effect of low temperature on..... 652
parasite of *Prunus* spp..... 365–366
toxicity of fruit acids to..... 388
fructigena, parasite of *Prunus* spp..... 366
laxa, parasite of *Prunus* spp..... 365–366
libertiana—
identity of..... 291–298
pathogenicity of..... 291–298
smilacina—
identity of..... 291–298
pathogenicity of..... 291–298
spp.—
parasite of *Malus* spp..... 365
pathological relations of..... 374–390
physiological relations..... 374–383
relation of tannin content of, to resistance of *Prunus* spp..... 389–390
taxonomy of..... 370–374
Scurf of *Ipomoea batatas*—
appearance of..... 787
injury caused by..... 787–788
occurrence of..... 995–1002
distribution of..... 787
Secale cereale—
host plant of *Puccinia phleipratensis*..... 211–212
occurrence of manganese in..... 353
transpiration of..... 602–607
Seed—
effect of green manures on germination of.. 1161–1165
oil, relation of green manure to injury of.... 1174
Separation of Soil Protozoa (paper)..... 137–140
Serious Disease in Forest Nurseries Caused by Peridermium filamentosum, A (paper)..... 781–785
Shantz, H. L., and Briggs, L. J. (paper)—
An Automatic Transpiration Scale of Large Capacity for Use with Freely Exposed Plants..... 117–132
Hourly Transpiration Rate on Clear Days as Determined by Cyclic Environmental Factors..... 583–650
Shedd, O. M. (paper), Variations in Mineral Composition of Sap, Leaves, and Stems of the Wild-Grape Vine and Sugar-Maple Tree..... 529–542
Sisymbrium officinale, host plant of *Cystopus candidus*..... 63
Smilacina racemosa, results of inoculation with *Sclerotinia smilacina*..... 295–296
Smith, E. F., and Bryan, M. K. (paper), Angular Leafspot of Cucumbers..... 465–476
Sodium—
effect of, on milk flow..... 562–563, 565–566
arsenite, effect of, on plant growth..... 459–460
salts, effect of, on plant growth..... 5, 10, 15ff
Soil—
arid, nitrogen content of humus of..... 909–916
bacteria—
effect of calcium sulphate on..... 772–774
effect of sulphur on..... 772–774
factors influencing longevity of..... 927–942
non-spore-forming..... 939
relation of, to crop-producing power... 855–869
slime-forming..... 940
moisture, description of apparatus for determining translocation of..... 142–144

Soil—Continued. Page
conditions, effect of, on protozoa..... 479–485
effect of—
alkali salts in, on germination and growth of crops..... 1–53
Vigna sinensis on properties of..... 443–447
heterogeneity of, in variety tests, method of correcting for..... 1039–1050
North Carolina—
mineralogical composition of..... 571–580
relation of petrography of, to fertilizer requirements..... 569–582
yields of *Gossypium* spp. on..... 578–580
Utah, analysis of..... 14
protozoa—
activity of..... 477–488
separation of..... 137–140
properties of, influence of growth of *Vigna sinensis* on..... 439–448
type of, effect on germination..... 1167
Soil Temperatures as Influenced by Cultural Methods (paper)..... 173–179
Soilstain—
causal organism of..... 998
effect of, on *Ipomoea batatas*..... 996
factors favorable to development of..... 996
symptoms of..... 996
Soilstain, or Scurf, of the Sweet Potato (paper)..... 995–1002
Soja max. See *Glycine*.
Solanum—
jasminoides, host plant of *Leptinotarsa decemlineata*..... 917
tuberosum—
absorption of boron by..... 879–884
analysis of..... 457–458
growth of mycelium of *Phytophthora infestans* in..... 74–80
hibernation of *Phytophthora infestans* in. 71–102
host plant of—
Fusarium spp..... 183–203
Leptinotarsa decemlineata..... 917–926
Phytophthora infestans... 59, 66, 67, 71–102, 183
Rhizopus nigricans..... 183
Sporotrichum flavissimum..... 186
Verticillium albo-atrum..... 186
infection of, by conidia of *Phytophthora infestans*..... 85–87
inoculation of, with *Fusarium* spp..... 201–203
relation of progeny of, to *Phytophthora infestans* in parent tuber..... 93–96
translocation of mineral constituents of. 457–458
Solar radiation, relation of, to transpiration. 631–634
Solidago—
bicolor, host plant of *Comandra umbellata*.. 134
caesia, host plant of *Comandra umbellata*. 134
juncea, host plant of *Comandra umbellata*.. 134
nemoralis, host plant of *Comandra umbellata*. 134
speciosa, host plant of *Comandra umbellata*. 134
Some Potato Tuber-Rots Caused by Species of Fusarium (paper)..... 183–210
Sorghum. See *Andropogon sorghum*.
Soybean. See *Glycine*.
Species, new..... 204, 466
Sphaeropsis malorum, effect of low temperature on..... 652
Spinacia oleracea, host plant of *Peronospora effusa*..... 59, 67
Spiraea salicifolia, host plant of *Comandra umbellata*..... 134

Page
Spore, resting, of *Phytophthora infestans*..... 98–99
Sporotrichum flavissimum, parasite of *Solanum tuberosum*..... 186, 201–203
Spray—
advantage of fineness in..... 1179–1180
advantage of uniformity in..... 1179–1180
flat, advantages of..... 1179
production of..... 1177–1179
variations in fineness of..... 1180
nozzle, new..... 1177–1182
adjustment of..... 1181
use of..... 1181
Stakman, E. C., and Jensen, L. (paper) Infection Experiments with Timothy Rust... 211–216
Star-apple. See *Chrysophyllum cainto*.
Steenbock, H. (paper), Diuresis and Milk Flow..... 561–568
Stellaria media, host plant of *Peronospora alsinearum*..... 59, 67, 68
Stereum subpileatum—
causal organism of honeycomb heartrot.. 421–428
description of sporophore of..... 426
distribution of..... 427–428
Stizolobium—
deeringianum, effect of crossing on length of pod..... 405–420
niveum, effect of crossing on length of pod. 405–420
Stoma, movement of—
factors influencing..... 1012–1029
relation of, to infection by *Cercospora beticola*..... 1011–1038
Sugar—
beet. See *Beta vulgaris*.
effect of—
on ammonification..... 1169
on carbon-dioxid evolution..... 1169–1170
maple. See *Acer saccharum*.
Sulphur—
effect of, on growth of plants..... 771–780
compounds, relation of, to plant nutrition..... 233–250
Sunflower. See *Helianthus annuus*.
Surface, F. M., and Pearl, R. (paper), A Method of Correcting for Soil Heterogeneity in Variety Tests..... 1039–1050
Surface floats, measurement of water velocity with..... 222–226
Sweet potato. See *Ipomoea batatas*.
Sweet-Potato Scurf (paper)..... 787–791
Swine—
deviations per generation in size of litter in..... 1150, 1154
fertility in, nongenetic factors affecting. 1146–1148
value of herdbook data..... 1148–1149
individual evidences of segregation in. 1154–1155
inheritance of fertility in..... 1145–1160
litter frequency in..... 1149–1158

Tannase, determination of, in *Malus sylvestris*..... 111
Taubenhaus, J. J. (paper), Soilstain, or Scurf, of the Sweet Potato..... 995–1002
Temperature—
cold-storage, effect of, on *Ceratitis capitata*. 657–666
effect of, on movement of water and vapor, and capillary moisture in soils..... 141–172
effective, in insect development..... 1185–1198

Temperature—Continued. Page
effect of, on germination of plants..... 1168
influence of, on growth of mycelium of *Phytophthora infestans*..... 77–80
low effect of, on certain fungi and bacteria. 651–655
relation of—
to insect development..... 1183–1191
to spread of mycelium of *Phytophthora infestans* in *Solanum tuberosum*..... 73
soil—
as influenced by cultural methods..... 173–179
effect of different cultural methods..... 174–179
Terminalia catappa, host fruit of *Ceratitis capitata*..... 659
Thatcher, R. W. (paper), Enzyms of Apples and Their Relation to the Ripening Process..... 103–116
Thurberia thespesioides, host plant of *Anthonomus grandis*..... 1189–1190
Timothy rust. See *Puccinia phleipratensis*.
Tomato. See *Lycopersicon esculentum*.
Tottingham, W. E., and Hart, E. B. (paper), Relation of Sulphur Compounds to Plant Nutrition..... 233–250
Tower, Daniel G. (paper), Biology of Apanteles militaris..... 495–508
Translocation of Mineral Constituents of Seeds and Tubers of Certain Plants During Growth (paper)..... 449–458
Transpiration—
plant, measurement of..... 583–585
relation of—
to environmental factors..... 637–646
to evaporation..... 634–637
to solar radiation..... 631–634
graphs, comparison of..... 627–631
rate, hourly, on clear days as determined by cyclic environmental factors..... 583–650
scale, automatic, for use with freely exposed plants..... 117–132
Tremella koreaense. Syn. *Gymnosporangium koreaense*.
Trichinae. See *Trichinella spiralis*.
Trichinella spiralis—
effect of—
artificial digestion upon..... 847–850
refrigeration upon larvæ of..... 819–854
refrigeration upon vitality of..... 837–845
variations in vitality of..... 845
Trichogramma minutum, parasite of *Profenusa collaris*..... 526–527
Trifolium—
pratense, effect of sulphur on growth of.... 239–241, 778–779
spp.—
effect of—
on ammonification..... 1169
on carbon-dioxid evolution..... 1169–1170
on germination of various seeds.... 1161–1166
Triticum—
aestivum, effect of alkali salts on growth of.. 4–11
dicoccum, occurrence of manganese in..... 353
sativum—
composition of seeds of..... 1162
effect of green manure on germination of. 1163
spp.—
absorption of boron by..... 880, 883

Triticum—Continued. Page
spp.—Continued.
method of correcting for yield of..... 1042, 1044–1045
occurrence of—
iron in..... 353
manganese in..... 349–355
resistance of, to alkali..... 22–24
vulgare, inoculation of, with *Puccinia phleipratensis*..... 211–212
Tuber-rot, occurrence of, *Solanum tuberosum* 183–210
Tumors in domestic fowl—
frequency of occurrence of..... 397–404
structure and location of..... 400–403
Turmeric. See *Curcuma longa*.
Turner, W. F., and Baker, A. C. (paper), Morphology and Biology of the Green Apple Aphis..... 955–994
Two New Hosts for Peridermium pyriforme (paper)..... 289–290

Urea, effect of, on milk flow..... 563–566

Vaccinium—
atrococcum, host plant of *Comandra umbellata*..... 134
nigrum, host plant of *Comandra umbellata*.. 134
vacillans, host plant of *Comandra umbellata*. 134
Valleau, W. D. (paper), Varietal Resistance of Plums to Brown-Rot..... 365–396
Vapor, water, effect of temperature on movement of, in soils..... 141–172
Variations in Mineral Composition of Sap, Leaves, and Stems of the Wild-Grape Vine and Sugar-Maple Tree (paper)..... 529–542
Varietal Resistance of Plums to Brown-Rot (paper)..... 365–396
Variety tests, a method of correcting for soil heterogeneity in..... 1039–1050
Veal, immature—
comparison with mature beef..... 667–711
digestibility of..... 684–708
Vedder, E. B., and Rommel, G. M. (paper), Beriberi and Cottonseed Poisoning in Pigs 489–493
Velvet bean, Florida. See *Stizolobium deeringianum*.
Venturia inequalis, effect of low temperature on..... 652
Veronica lederaefolia, host plant of *Peronospora grisea*..... 59, 67, 68
Verticals, effect of varying numbers of, on the accuracy of current meter gaugings.. 226–231
Verticillium albo-atrum, parasite of *Solanum tuberosum*..... 186, 201–203
Vicia sepium, host plant of *Peronospora viciae*..... 59, 64, 65, 67
Vigna sinensis—
absorption of boron by..... 881
effect of growth of, upon soil..... 439–448
influence of growth of, upon properties of soil..... 439–448
Vitis—
cordifolia—
composition of—
leaves..... 536–538
sap of..... 529–535
stems of..... 536–538
variations in mineral composition of... 529–542
vinifera, host plant of *Plasmopora viticola*.. 67

Water maple. See *Acer saccharinum*. Page
Water vapor in soils, effect of temperature on movement of 141–172
Weed, fate and effect of arsenic on 459–463
Weekly publication, announcement of i
Weir, J. R., and Hubert, E. E. (paper), A Serious Disease in Forest Nurseries Caused by Peridermium filamentosum 781–785
Weir—
box—
effect of—
shape on discharge of 1129
size on discharge of 1129
discharge formula for 1135–1136
new irrigation 1127–1143
advantages of 1143
construction of 1141–1143
discharge from 1137–1139
experimental and computed discharges from 1139–1141
use of 1141–1143
notch—
Cipolletti, flow through 1073–1082
circular, flow through 1088
edges, requirements of, for free flow .. 1088–1090
flow through 1051–1113
effect of contractions upon 1091–1098
measurement of head in 1090–1091
relation of notch length to 1098–1101
rectangular, flow through 1063–1073
Weir—Continued. Page
notch—continued.
submerged, flow through 1101–1106
triangular, flow through 1083–1088
Wentworth, E. N., and Aubel, C. E. (paper), Inheritance of Fertility in Swine 1145–1160
Wheat. See *Triticum*.
Wilson, views on perpetuation of *Phytophthora infestans* 97
Wilt, bacterial, of cucurbits, dissemination of 257–260
Withers, W. A., and Carruth, F. E. (paper) Gossypol, the Toxic Substance in Cotton-seed Meal 261–288
Wolf, F. A. (paper), Further Studies on Peanut Leafspot 891–902
Woodworth, C. W. (paper), A New Spray Nozzle 1177–1182

Zea mays—
absorption of boron by 884
composition of seeds and seedlings of. 456–457, 1162
effect of—
alkali salts on growth of 23ff
green manure on germination of. 1162, 1165–1166
translocation of mineral constituents of .. 455–457
occurrence of manganese in 353
resistance of, to alkali 22–24
Zinnsmeister, C. L., and Rosenbaum, J. (paper), Alternaria panax, the Cause of a Rootrot of Ginseng 181–182